

THE DIVERSITY OF THE INSECT FAUNA OF FOUR SPECIES
OF SOLANAE PLANTAEON (L.) GENTILY AND
ITS RELATIONSHIP TO THE PLANT ARCHITECTURE.

By

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Be my friend, too

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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	100
LIST OF TABLES	100
LIST OF FIGURES	100
ABSTRACT	100
INTRODUCTION	100
LITERATURE REVIEW	100
Ecological Role of <i>Galinsoga</i>	100
Species Invasions: A Function of Plant Architecture.....	100
The Nutritional Quality of Non-Plant.....	100
MATERIALS AND METHODS	100
Insect Community of <i>Galinsoga</i>	100
Plant Selectivity of <i>Solidago</i> species for <i>Galinsoga</i>	100
SOLIDAGO (Labiatae).....	100
Plant Selectivity of <i>Solidago</i> species for <i>Quinchamalium</i>	100
QUINCHAMALIUM (Psidaceae).....	100
Life Cycle of <i>Galinsoga</i> (Lobelia) and <i>Galinsoga</i>	100
GALINSOGA.....	100
Water and Nutrient Content.....	100
Plant Architecture and Insect Herbivory.....	100
RESULTS AND DISCUSSION	100
The Insect Diversity of <i>Galinsoga</i>	100
The Physiphagous Fauna.....	100
The Detritivorous Fauna.....	100

Host Suitability of <i>Salixigia</i> sp. for <i>Spodoptera litura</i> (L.)	49
Larval and Adult Performance	49
Microsite and Larval Diet of <i>Spodoptera litura</i>	60
Reproduction and Feeding Preferences	71
Host Suitability of <i>Salixigia</i> sp. for <i>Sparganothis plutea</i> (Reinwald)	79
Plant Archetypes and Insect Diversity	80
CONCLUSIONS	91
APPENDIX	94
LITERATURE CITED	103
ACKNOWLEDGMENTS	105

List of Tables

	Page
Table 1. Average densities of plants (no. of plants/m ²) in the 7 populations of <i>Salvadora persica</i> ssp. in Chile	19
Table 2. Phytophagous insect fauna of <i>Salvadora persica</i> ssp. in Chile	20
Table 3. Insecticidal arthropods associated with <i>Salvadora persica</i> ssp. in Chile	20
Table 4. Developmental time from hatching to hatching, number of adult stages, and weight of newly emerged adults of <i>Geocoris salvadorae</i> (Felt) with each of the four diets	30
Table 5. Number of eggs/oviposition and life span of males and females obtained of <i>Geocoris salvadorae</i> on each food spectrum	40
Table 6. Water and nitrogen content of leaves of food plants for the larvae and adults of <i>Geocoris salvadorae</i>	43
Table 7. Correlation of larval and adult performance with leaf water and nitrogen content	44
Table 8. Body indices for PGRs and oviposition of males and females of <i>Geocoris salvadorae</i>	45
Table 9. Larval and adult performance of <i>Geocoris salvadorae</i> on the four host plant species	50
Table 10. Average height of the plant, total leaf area, and size of PGRs, number, and weight of phytophagous, insecticidal and total insects species collected on <i>Salvadora persica</i> in four periods of the growing season in 1993	53
Table 11. Average height of the plant, total leaf area and size of PGRs, number, and weight of phytophagous, insecticidal and total insect species collected on <i>Salvadora persica</i> in four periods of the growing season in 1994	55

Table II.	Analyses of variance on height, basal leaf area and size of above-ground parts of gramineous plants at three different heights	267
Table III.	Coefficients and the derivative of architectural ratio for the species of <i>Setaria</i>	268
Table IV.	Correlation of measures of the architectural complexity of <i>Setaria</i> plants with the number of leaf-sheath structures associated with them	269

Figure 1. Schematic drawing of a <u>Salix</u> plant and the number of phytophagous insect species in each order feeding on the different parts of the plant	33
Figure 2. Annual distribution of the feeding stages of the most common insects (adults) to <u>Salix</u> (top), in leaves of <u>Salix</u> (middle) and in twigs (bottom)	33
Figure 3. Relational graph to Salicetella	33
Figure 4. Relative contribution of the 200 species of insects associated with <u>Salix</u> to Salicetella	33
Figure 5. Seasonal distribution of percent tree predators, phytophagous and total insects found associated with four species of <u>Salix</u> to Salicetella	43
Figure 6. Developmental time of males (M) and females (F), of <u>Apanteles</u> (<u>Apanteles</u>), number of adults reared (N) and number of eggs/oviposition (E) in relation to total surface (leaf area) of the leaves of four species of <u>Salix</u>	43
Figure 7. Square root of the number of phytophagous insect species and square root of the total number of species in relation to the total leaf area of the host plant	53
Figure 8. Relationship between total leaf area and the square root of the number of phytophagous insects and to the total number of species (developing species) in 1991 and 1992	53
Figure 9. Relational slopes to total leaf area (as a measure of the plant architecture) and to the number of phytophagous insect species in four different species of <u>Salix</u>	53

Abstract of Dissertation Presented to the Graduate School
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**THE DIVERSITY OF THE INSECT FAUNA OF THE SPICES
OF *SOYBEAN* (CROTONIA) IN CAMPANHA, AND
ITS RELATIONSHIP TO THE PLANT STRUCTURE.**

by

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The insect fauna of four species of *soybeans*, *Glycine max*, *G. soja*, *G. soja* and *G. soja* *hirsutissima*, were surveyed during four years in Belo Horizonte, Minas Gerais. The 200 epigaeous and 120 haemolymph (excluding spiders and gallinators) species are listed and classified according to frequency, path, host range, part of the plant attacked, life stages affected, and associated gallinators species. Only 16 of the epigaeous species were recorded by gallinators and 80% of these are known and the other 16% are scientifically unrecorded.

Leaf water and nitrogen content of the leaves of the four *Glycine* accessions significantly affected development and fecundity of two specialist herbivores: *Geocoris luteos* (Heteroptera) and *Geococcyx gryllioides* (Heteroptera). *G. soja* leaves had higher water and nitrogen content

and was the preferred host for both insects. *J. canescens* had significantly lower leaf storage content for performance of both insects on this host and equivalent to performance on *J. gigantea* and *J. leucostachys*; because of the low leaf water content of these two plant species.

The insect populations we surveyed and the number of leaves, leaf area, plant height and flower stalk size were determined for each species of goldenrod during five periods of the growing season in 1993 and 1994. Total leaf area held explained the variability in insect diversity within the three *Solidago* studied. Plant Frequency, Leaf Maylene and environmental factors did not a detectable effect on DHA variance. Chemical defenses and nutritional quality of the host plant may be responsible for unexplained variability.

The seasonal build up of the insect fauna closely fits Lester's (1984) hypothesis model for the interaction between plant architecture and chemical defenses in changes in the insect community during the growing season of a perennial herb.

Seven insects are rated as possible biological control agents (Garcia and James (attacking adult), *Sphecodes* (adult) and *Sphecodes* (juvenile) (leaf chewer), *Lygocoris* sp. 1 and *Conostethus* (attacking) (leaf miner), *Leucania* (caterpillar), (leaf gall miner), *Lebia* (adult) (leaf feeder) and *Schizoglossa* (flower gall miner).

Bruchomorphs act as a predator for many beneficial insects, but for only a few plant insects.

INTRODUCTION

Plants of the genus Salal are widespread throughout the coastal states. About 15 species of this perennial herb occur in Florida (Merrill, 1929). Four species are very likely to be found in the old fields, fence rows, or roadsides in the Bremerton area. They are Salal gigantea L. var. gigantea (Pursh) treated by some as S. glauca (Pursh) var. gigantea (Pursh) (Merrill 1929); S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929); S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929); and S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929). S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929) is the only species of Salal that occurs in the Bremerton area (Cope et al., 1971). S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929) and S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929) are confined to the southeastern region of U.S. (Cronquist, 1968). These three species can be easily distinguished from each other by differences in size, form, and structure of the leaves and inflorescences, and in flower phenology. All four species begin to grow in July/early August and the blossoms appear in the beginning of October. They build up their structure each year, as trees, vines, shrubs and roots are added to the plant through the growing season. None of these species is a pest of cultivated plants in the United States. However, S. glauca (L.) Greene var. gigantea (Pursh) (Merrill 1929) is a host for some diseases that are often economically important trees (Maderly and Peterson, 1970; Sorenson et al., 1980). It also increases atmospheric salinities that inhibit germination and growth of surrounding vegetation (Hartman et al., 1970). Two species and S. glauca are naturalized in non-temperate areas and forest nurseries in Europe. A biological control program of Salal has been proposed by Cope (1971) and Balfour

(1996). A survey of natural enemies as biocontrol potential biological control agents in new living place in North America (Beldi et al., 1999).

On the other hand, these plant species have some beneficial properties that could be explored in their native land, where they are not considered noxious. *By definition, non-native* is an alternate source of food for arthropod predators and parasitoids of crop pests (Witten, 2000). It also provides chemical substances that have insecticidal characteristics (Rousse et al., 1997). Nuisance plants are an important source of pollen and nectar to bats (Pell, Chressall, 1992).

The general objective of this study is to present basic information on the floral species structure of galloping. Such information is relevant of galloping to be monitored, either as beneficial plants that should be cultivated or non noxious, or as undesirable plants that should be controlled. A strategic control program could prevent further and by less expensive if better predictions could be made as which of the phytophagous species would be good candidates for biological control agents. The chance of finding successful agents increases with the knowledge of the proportion of polyphagy among phytophagous insects related to the target pest (Lambin and Schmid, 1999).

To assess information on the relationships between the insect community and galloping plants, and their implications, the following points will be considered:

1. The richness of the different taxa of insects on galloping and their relationship to the structural characteristics and phenology of the host species.
2. The specificity of phytophagous insects and their distribution in galloping.

1. The correlation between the total number of insect species and the arthropod complexity of the host plant.
2. The dietary strategies of the phytophagous insects most frequently found in *Artemesia*, considering food and habitat preferences among the four *Artemesia* studied.

LITERATURE REVIEW

Ecological Role of Solenopsis

The genus Solenopsis belongs to the subfamily Aenictinae of the family Formicidae. Plants of this genus are found in a variety of environments, from dry to semi-humid, sandy, and calcareous to fertile land of wet forests, from open, sun-drenched and shaded to shady areas (Kugler, 1971; Rabelo, 1981). It is represented by more than 100 species distributed to the Americas, Europe, Africa (Fernández, 1980) and Japan (Takemoto, 1980). Most of the species are endemic to North America, a few to South America and Europe and one to the Asian (Fernández, 1980).

Solenopsis are generalist herbivores, characteristic of secondary successions. They regenerate vegetation by clipping, and usually by producing great numbers of winged queens (Jensen et al., 1980).

The large masses of gallworms make them very attractive as agricultural pests. They are adapted to a variety of associations (Rabelo, 1981) and from summer to late fall, when most other plants have stopped flowering. Solenopsis worms are also valued by beekeepers, since they are one of the few sources of pollen and honey in late fall (Jefferson and Lonsdale, 1979; Tereza, 1980; Petalane and Santos, 1977; Rabelo and Moreira, 1981). Some pollinator insects such as butterflies (Bierlich, 1971; Tereza, 1980) and bees (Moraes, 1979; Robert and Rabelo, 1981) prefer the easily accessible flowers of gallworms. Polybia dominula (P.) a social wasp, and the honey bee Apis mellifera ligustica (P.) selectively visited flowers of gallworms, generally using the surface of the flowering plants in these gallworm

Table 10, continued (See Mitchell and Paoletti, 1991). The main publications of polyphenols are: hexatannol (*Quercus milliflora* Linn.), heptatannol (*Quercus* sp.), octatannol (*Quercus ilex* Linn.), pentatannol (*Quercus* sp.) and syringin (Flame) (Barber et al., 1990). Some monographs also mention extract of *Calliandra* spp., among other plant species (Paoletti et al., 1991; Mitchell and Paoletti, 1991).

Flavonoids have other useful properties. Some of the most potent (0.0001-0.01%) are the tannin-elliptic tanins, of which the water, make a green dye that can be used for tanning (Barber, 1991). *S. quercifolia* (L.) and *S. nigra* L. showed potential as tanninoids and tannin-proteins (van Huchman et al., 1990). *S. nigra* L. and *S. quercifolia* can be used for all protections (Guermon, 1976; Arribalzaga and Busto, 1972). Perhaps the most interesting property of tannins (esp. in their chemical constituents) (Barber, 1991; Paoletti, 1991; and Mori, 1991). Compounds such as ellagotannins, galloyltannins, flavonoids and tannins were extracted from potential plants (Paoletti et al., 1991; Guermon et al., 1976; Mori et al., 1991). A survey in the 1980 showed that *S. nigra* can cure 15 species of plants used to kill termites, suggesting their bio-chemical properties should be scientifically investigated (Guermon, 1976). Some of the chemical substances in potential may also have insecticidal properties. Poly-oxotannins, *Brachystegia utilis* (G. L.) are inhibited by extracts of the leaves of *S. nigra* (Paoletti and Paoletti, 1991). Insects exposed to these extracts showed characteristic rotting behavior. A notable extract of extracts of *S. nigra* (G. L.) incorporated here the most completely inhibited hatching of eggs of *Brachystegia utilis* (Mori et al., 1991).

Some of the substances produced by *Solidago* spp. inhibit germination and growth of the surrounding vegetation (Kochhar et al., 1978). This allelopathic effect of gallicoids plants may have important economic implications. For example, growth of black locust was reduced 80% by adding dried foliage of *S. gigantea* var. *gigantea* to the soil (Larsen and Johnson, 1981). A water extract of *S. gigantea* also inhibited height growth, secondary apical branching and dry weight increments of *Phaseolus vulgaris* L. (Hedtke and Nieroth, 1982). Furthermore, nutrient uptake and growth of young sugar beet (*Beta vulgaris* L.) was inhibited by water soluble compounds produced by *Solidago* spp. (Flitter et al., 1981). The production of these allelopathic substances like gallicoids strongly competes. This result, associated with right vegetative regeneration, allows them to form dense stands, crowding out other vegetation. In certain regions of Europe, where gallicoids have been introduced, they damage seedlings as well as young and old trees in regeneration areas. Gallicoids are replacing the native vegetation, consequently reducing the indigenous phytophagous and arthropagous insect populations because they seldom feed on it. Gallicoids are now considered aggressive pests of forest resources in Europe (Flitter, 1978). In Japan, gallicoids have become one of the most dominant weeds in railway right of ways, pastures and other uncultivated situations, over urban areas (Ito et al., 1978). *S. gigantea* (Vahl) (L.) *S. gigantea* var. *gigantea* (L.) *S. altissima* and *S. canadensis* have wide distributions and were imported over 100 years ago into Europe by gardeners (Eger, 1976). Since these three species may become invader weeds they are now rarely recommended as ornamentals (Zedler, 1986; Capo, 1977; Rocco, 1977). *S. gigantea* var. *gigantea* is the one

of the most noxious and invasive plants in Japan (Takayama, 1996). Studies on chemical control of *calystegia* show that some herbicides are effective against this plant. *S. glycinoides* is susceptible to 2,4-D and glyphosate in Quebec. It is also affected by paraquat, dicamba and alaro, but resistant to 2,4-D. In these treatments, decline with age (Bouchard and Bois, 1994). Glufosinate + dicamba + 2,4-D proved to be effective to control *S. grandiflora* var. *gigantea* (= *S. altissima*) in Germany (Benzing, 1996). Glufosinate alone has no effect on this species in forest microsites there is Canada (Vessey, 1996). In Japan, *S. grandiflora*, var. *gigantea* (= *S. altissima*) was completely controlled by post-emergence application of amine, dicamba, diclofop and paraquat (Ito et al., 1994), and amine + diclofop (Kishiguchi and Ito, 1994). Chemical control of *Calystegia* spp. was reported by Hertrich and Böhme (1972), Mühlemann and Hertrich (1977), Hartung et al. (1979), Löffelholz and Peters (1983), Peters and Löffelholz (1984), Jensen (1987), Gentile and Gaudichet (1990) and Peters (1993). In forest microsites and regeneration areas of Europe, where *Calystegia* spp. are aggressive and troublesome weeds, they are controlled by costly mechanical measures or by applying herbicides to high concentrations (Hartung, 1979). This is expensive and carries the risk of environmental contamination.

Calystegia has several characteristics of great importance for biological control. It is a structurally complex plant, with several points of attack to phytophagous insects. Although the aerial parts do not make whorls, the flowers are available throughout the year, presenting an ecological continuity. This would be important in maintaining and building up a population of natural enemies. *Calystegia*, reported to Europe and Japan from North America, are free from their

adults of Leptophyes. Damage caused by the indigenous phytophagous insects is only where not apparent (Kings, 1971; Dettler, 1976). In North America, only phytophagous insects are found associated with the many unrotated pinewoods. Many of these, restricted to the genus Leptophyes, cause severe damage to certain species of Quercus (Prest and Werner, 1974) in the eastern states (Carrasco and Hernandez, 1976; Rosales and Rose, 1981). Rose et al. (1976) recorded 46 adult species from Q. coccinea in northeastern Ontario. Over 90% of this adult fauna belong to a group of seven species which form a characteristic sequence of trifoliate occurrence from early to late summer. In central New York, Peugler (1979) reported 23 species of adults associated with old field pinewoods (Hartlage 1981). Only six genera accounted for 87% of all lepidopterans which can be attributed to 20 families within this forest in pinewoods. Laspeyresia (L. naevia), was the most common species. The leaf beetle fauna associated with Leptophyes spp. in central New York is composed of nine species/this faunae that feed only on galliferous and annual, tree generalists, and tree herbivores. The specialists, Trichobius (leptophyes L.) and T. (leptophyes) Fleut., account for 80% of all the beetles collected (Peugler and Rose, 1980). Both genera host many species of insects which stimulate gall production on stem, leaf, root, or rhizome (Rose, 1981). These gall insects may play an important role in the induction of the plant life history patterns. The galls of Quercus palustris (Hickory) (Ferguson and Ferguson, 1979) and Quercus rubra (Red Oak) (Hickory) (Ferguson and Ferguson, 1979) are reported to have propagule production (Ferguson and Ferguson, 1979). The presence of these two galls and the gall of Leptophyes

phytophagous Linn (Gochring 1981). Increased stem production, decreased current infestation, and increased seed reproduction of *Populus* by *S. canadensis* (Barrett and Brinkman, 1973). Decrease of other gall-formers on available hosts on the plants of the plant.

The possibilities for the biological control of galls on *Populus* were fully discussed by Cajet (1971) and Winter (1979). Cajet (1971) surveyed, during one year, populations of *S. canadensis*, *S. ciliatella* var. *guttata*, and *S. ciliatella* in Ontario. He recorded insects reported to attack, attack, feed, flower, and seeds. He recommended further studies on the following insects as potential biological control agents: two tortricid species that bore nests and stems, *Laspeyresia populiella*, *Laspeyresia populiella* (Linn.), and *L. populiella* (Linn.), three species of stem-gall makers: *Baliosus gallophagus* (Linn.), *Phyllocoptes populiella* (Clerc), and *Neuroterus gallophagulus* (Bergroth, 1911), and the leaf feeder *Trichophyia canadensis* (Say.). The author reported this beetle as being the most important phytophagous species on galls on *Populus* in Canada. Further studies (Reed and Barnes, 1979) showed, however, that *S. ciliatella* and not *S. canadensis*, is the major defoliator of *S. canadensis* in southeastern Ontario. Bellmer (1979) completed Cajet's studies by discussing the effect of insects with the borers and giving guidelines for further research. Bellmer and Barnes (1979) summarized grouped the insects reported from *Populus* spp. in a list sorted by order, specifically and genera. In Japan, the beetle *Neuroterus gallophagulus* (Bergroth, 1911) is reported as the major defoliator of *S. ciliatella* var. *guttata* (= *S. ciliatella*). This beetle is being studied as a possible biological control agent (Matsuo, 1980).

In the United States, goldbeetles are also, in many cases, considered harmful plants. It is generally believed that goldbeetles cause hay fever. However, unlike other plants such as ragweed, grasses, and weeds, goldbeetle pollen is not whistlers but is transferred from plant to plant by a variety of pollinators such as bees, beetles, butterflies and birds (Danner et al., 1981; Shattock and Peatly, 1981; Bessell, 1992). In reality, the many forms of goldbeetles are being moved by the same insects as the reproductive flowers of other plants.

Although the hay fever problem is a myth, the number of disease-producing organisms hosted by goldbeetles is a fact. Some of these organisms attack plants of economic importance. For example, *S. callosoma* hosts *Botryosphaeria clavigerum* S. C. ex Thüm (potato blight) which attacks rootlets and corms, *Botryotinia fuckeliana* (Sacc) Sacc. (potato rot) which also occurs on cattie and sugar beets, and *Colletotrichum ciliigera*, which is a finger smut on *Pisum sativum* L., *S. hispanica* L. and *S. galericulata* L. (Wobert and Anderson, 1994; Besser et al., 1998). In addition, the *fungus Colletotrichum gloeosporioides* which attacks *Ornithogalum* from its plantlets and corms (Danner, 1992) and *Cercospora* (Anderson and Anderson, 1992).

Goldbeetles may be an alternate host for pest insects that would otherwise be the overwhelming goldbeetle. While crop plants are no longer available, it could, on the other hand, host beneficial insects such as predators and parasites that could fly to crop plants and keep pest populations low. Shattock (1981) cites several examples in which the biology of insect pest is altered by maintaining the natural vegetation on the border or within crop fields. The weeds offer an alternate source of food, shelter, overwintering sites, breeding and

writing areas for important predators, and perhaps even better for possibilities of crop pests. *Lygus punctatus* var. *giganteus* (Fig. 3) is cited as one example of a pest that provides an alternate food element (the adult, *decrepita* and the postoviparous *adolescens* (Beckmann, 1970; Beckmann, 1972; Beckmann, 1973a; Beckmann, 1973b; and others) (Alberti, 1970). The threecelled elliptical cells found on the stems of *L. giganteus* by the author and with *Lygus punctatus* (Beck.) are as important, but whereas the parasitic insects in southeastern Pennsylvania, of 12 primary predators that emerged in the series of 2013 and 1974 from these galls, seven were known to parasitize a variety of insect pests during their winter generations (Plaisted, 1950). Bergman and O'Neill (1960) reported that galls on *Salicaceae* spp., which are *L. punctatus* and *L. giganteus* (L.), *Salix* spp. (Bentham), *L. laevigatus*, and *Quercus* spp. A small population of the grasshopper *Hemiphonus pectoris* (Porter, 1961) has declined and disappeared due to a high rate of infection with the parasite *Neuroterus oligospilus* (Schiff). Other grasshopper species were unaffected or had low rates of infection. The high percentage of infection in *L. giganteus* probably was related to a low host load, where the grasshopper fed primarily on *Salicaceae*, *alnaceae* (Porter, Oberholser, and Rutherford, 1970).

Surveys of insects related to a given plant species or to a plant family frequently have as objectives the identification of potential pests related to the plant itself or to other economically important plants. Surveys are also made to search for biological control agents. A survey of gall-forming insects would serve both purposes and would detect the presence of important predators and possibilities of crop pests. Such

information would be of major importance for the understanding of the ecological role of this plant in ecosystems.

Species richness: A measure of plant biodiversity

Although not a great diversity of phytophagous and entomophagous insects, Pott (1994) reported 250 species on *L. gmelini* viz., *gracilisognathus* Ryb., and *L. gmelini* var. *leptophylla* (Q. M. Hahn). In a single year, seasonal distribution of the host plant reflects the number of insect species associated with it. It was suggested earlier (Borchsenius, 1981) that the diversity of the associates of a plant taxon increases with the range of the plant and so linearly correlates with the geological age of the plant taxa. In other words, the number of insect species associated with a given taxon would increase slowly and continually although little over long periods of geological time. There is evidence, however, that in assemblages of the local community occurs a geographical limit. Present conditions are important in determining insect diversity, and it has been shown that the equilibrium reached depends largely on the geographical range of the plant (Hans, Hiltbrink, Stoeberl, 1994). The geographically closer the collection areas are considered, the larger the range of the plant, the larger the number of phytophagous species associated with it. This principle is based on Hurlbert and Wilcox's equilibrium theory of island biogeography which postulates that "the number of species of a particular taxonomic group in an island will reach equilibrium, and that the equilibrium number of species is a function both of the area of the island and the distance from the species source" (Hiltbrink, 1994).

Jensen (1971) suggested that "host plants are subject to a sort of regulation for phytophagous insects". Following this point of view, the

theory of island biogeography has been extended to include any situation where isolated, discrete patches of habitat are surrounded by disturbance areas. Neter (1994) tested this hypothesis by analysing the relationship between 100 species of leaf-mining insects and the range of their 28 host species of trees. He found that species number increases continuously with increasing area. Many other studies have confirmed that host geographical range is the most important determinant of the number of species associated with a tree plant (Dethier, 1990, 1991, Dethier et al., 1992, Leterrier and Dethier, 1992, 1993, Strong and Levin, 1994, Gossner et al., 1996, Cornelli and Rzedowski, 1997, Leterrier and Prati, 1998, Sonnay et al., 1999; Chiarolla and Wilson, 1999; Cornelli, 1999). These epiphytic plants are more likely to be found and utilised by insect species adapted to the various disturbance situations occurring in the plant's geographical range. Dethier, Leterrier and Gossner (1999) showed that the number of habitats occupied by each species of caterpillar is dependent (logistic) but a mixed effect upon aggregate species richness, with plants that grow in tree habitats supporting more species of insects.

Area per se, however, is not the only mechanism responsible for species-richness. For instance, Leterrier and Dethier (1997) compared standard species-area curves for perennial herbs, woody shrubs, seeds and other annuals and monocots. They found a significant (albeit small) difference in intercept among the regression lines of these five series of plants. For a given size of geographical range, each group of plants has a characteristic number of insect species associated with it. The number of insect species associated with woody shrubs is equal that of perennial herbs, which is larger than seeds and other annuals, which is turn is larger than monocots (woody shrubs larger than perennial herbs but not

statistically significant). They next tested the effect of Cenozoic radiation on diversity of a plant's epibionts, based on the idea that species with several relatives in the same geographical area will exchange herbivores more easily than unrelated plant species (the authors used the word *exchange* to refer to the "supplanting of a herbivore (adult or an evolutionary line state)"). They sought proofed evidence to support this notion, and to make an account for the differences in intercept among the regression lines. After eliminating the "apparent" influence of time (LGM) (weird shifts are more apparent and thus more likely to have higher colonization and lower extinction rates than seeds and insects) because insects had more time (soils associated with them than seeds and other insects), the authors suggested that the evidence of the insect fauna was a function of plant architecture. Individual species of plants have different growth forms. They may be easier or difficult to colonize provided for phytophagous organisms and to physical size of the herbivore. They also suggested that plant density and its chemical characteristics. The herbivore variation between plant species influences the number of insect species associated with them. The plants with a wider size of geographical range are complex, the richness of associated insect fauna follows the sequence *transvaalensis* (Lötter and Schröder, 1977; Bothma, 1977; Stoen and Botha, 1981), i.e., 16 species with the decrease in architectural complexity of the plants.

The term "architecture" is defined by Lötter (1982) as "a variety of plant attributes such as size and growth form, seasonal development, persistence and variety of above ground parts". Plants with a more complex architecture have more niches available for phytophagous insects.

as well as for predators and parasites, supporting a higher equilibrium species pool. Lawton (1986) discusses the ten hypotheses that attempt to delineate the effects of the components of architecture: the size per se hypothesis and the resource diversity hypothesis. The size per se hypothesis states that larger plants are more apparent and thus more likely to be found and utilized by insects, in ecological and evolutionary time, than are small plants. If the number of insect species on a plant is a balance between recruitment and extinction, then larger plants have more species associated with them because they have a reduced extinction rate. As Lawton (1986) reports, very few experiments are available demonstrating the effect of size on species richness. However size and resource diversity are often positively correlated and it is difficult to disentangle the contribution of each one to the overall diversity. The resource diversity hypothesis means that plants that have more feeding, resting, breeding, overwintering and hiding places available support more insect species than plants with fewer resources. Plants with greater diversity in their basic feeding sites are likely to have more insect species-rich, at least to just insects and insects are specialized to their host choices. Unlike a particular structure, for instance the absence of flowers and fruits on trees, habitat specialization dominates (Lawton, 1986). Other resources such as shelter, oviposition and overwintering sites and a place to hide from natural enemies are also important requirements for phytophagous insects. These resources are more available on more structurally complex plants, such as trees and shrubs than on simple ones, such as herbs. Trees and shrubs have resulted in a variation in microclimates, foliage density and thickness, permitting a colonization of herbivores either vertically, on taller plants,

or herbivory, among plants of different ages. Other factors to be considered in availability of resources are the seasonal changes in the general palatability of the foliage and stem (chemistry, tannins, etc.) that might cause a turnover of annual specialist insects. Host species with large seasonal changes in their palatability should be attacked by a greater variety of insects than other plant species which show less change.

For a given herbivore the way plants differ in resources available to herbivores, or even that resource diversity is the major contributor to the patterns of insect diversity. But, as noted before, resource diversity varies in parallel with size, and one can hardly be excluded from the other.

There is evidence, besides that already cited, of the influence of plant architecture on the diversity of phytophagous insects that is consistent with size, or number, of individuals observed above. Karshik et al. (1972) sampled plants and *Homoptera* in three old fields in northeast Florida. They found that insect diversity was highly correlated with the foliage height diversity over all three fields. The greater richness of coleopterids on Pinelands trees and shrubs is explained by the frequency of the host plant, number of relatives, plant height and leaf size (Beavens and Madala, 1981). Deciduous plants growing vertically supported a greater number of the drywoodid beetles, *Allochus ciliatus* (Perty), than plants growing horizontally (van Thiel, 1980). Among the two oak species in the New Jersey (1968) soil series, *Quercus palustris* (W.M.) Michx. forms a dense and persistent stand, while *Quercus alba* (L.) L. produces only a loose lattice of litter which rapidly disappears. Studies have determined that the attack of the *Q. palustris*

species richness responsible for the larger assembly of sap-feeding insects in this species than in *L. alatum* flies (Brown, 1977). In another study, Tilney and Brown (1981) compared the phylogenetic similarity, *Species richness* with a phylogenetic component, *Species richness* (S.),. They found that *L. alatum* exhibited a wider and more diverse assembly of sap-feeders than *L. alatum* flies. Species richness of needle-leaf invertebrates in central Britain is correlated with tree species range, size, and diversity (Brown, 1977). Many studies and observations in Europe support more species of herbivore insects than potential hosts of the pine sawfly. Individual species of *Arctia* trees are attacked, on average, by more species of microlepidoptera than are shrubs and herb species attacked more than herbs (Orton, 1977).

The effect of canopy changes on invertebrate availability was subject to review (1990), Thompson and Peltz (1990) and Thompson (1990). In each case, additional species enter the system to utilize the resources that are added to the plant as the tree progresses. Effects of plant architecture are not just apparent in gross comparisons between major growth form and tree. It can also be detected among closely related groups of species. Plant size and growth form of plants of the family *Lamiaceae* within the British Isles have a significant effect on the number of species of aggregated herb among larvae (Lawton and Price, 1976). Price (1988) analyzed the related assembly of 33 species of *Quercus*, 14 large and 14 small. Among 107 species he found a highly significant correlation between the total number of phytophagous insects and a measure of the overall architecture of their host plants. The *Q. ilex* used to cultivate the architectural rating were height of plants, mean number and area of fruits, development of woody stem and

species complexity. Price and Wilson (1970) showed that larger species of willow in Illinois support more species of specialized herbivores than small ones.

The positive relationship between species richness and host complexity is not universal, however. For example, the number of specialist gall-wasps on large species of North American oaks are not notably higher than on small species (Gentry and Williams, 1979). This may be a reflection of the difficulty in detecting architectural effects within a closely related group of plants (Larson, 1982).

The architectural complexity of the host plant may affect the life history strategies of insects. For instance, Kühn (1981) suggested that the almost complete absence of filigree moths in some groups of temperate Diptera and Heteroptera in arboreal habitats (he compared with their low incidence in ground and field) is related to the architectural complexity of trees. Stems and branches of a tree are usually more widely spaced than those of ground and herbs. Insects on a tree have greater freedom of movement to all these damages and the relationship of wings and the ability to fly may be more advantageous than filigree. However, Bann (1980) discussed Bäteff's hypothesis showing that architectural complexity of trees did not favor fully winged herbivores in arid, although in my view one can also see filigree.

In temperate regions, there is a seasonal progression of the fauna on a plant. The number of phytophagous insect species on a patch of leafless larvae probably reaches a peak in late July and early August, with only few being found on the plant throughout the whole season (Larson, 1979). In a strict analysis of these data, the author suggested that the variation in number of species of phytophagous insects

are due to a differing quality of frass as food during the growing season, because during most of the summer the quality of protein in the plant is considerably worse than usually regarded as optimal for new insects. At the same time, there is an increase in the levels of tannins, lignin and cellulose. Lester's findings were very similar to those of Keay (1976) on leaves of oak trees, and both authors agreed on the plant chemistry explanation for the seasonal variation in the phytophagous fauna of bracken and oak. However, Lester (2000) suggested the idea that plant architecture instead of plant chemistry might better explain the variation in the number of insect species throughout the year.

The Selective Feeding of Insect Plants

While herbivores and plant architecture influence the number of insect species on a plant, plant defense strategies (including nutritional, chemical, physical and behavioral mechanisms) affect the kind of insects which colonize the plants. Less than a third of the terrestrial arthropods have achieved the ability to feed on non-plants (Southwood, 1978), apparently because of the difficulties that phytophagous organisms face in bypassing plant defense mechanisms. Plants are known to produce all kinds of poly-phenols such as tannins, flavonoids, saponins, alkaloids, glycosides, resins and lignins (Bergelson, 1979) which affect growth, behavior and population dynamics of phytophagous insects (Kane, 1999). In the course of their coevolution with the host, insects respond to these plants' defenses by evolving detoxifying mechanisms (Odeberg, 1991). After overcoming this difficulty, phytophagous insects start to have to face nutritional hurdles. Increased research on insect nutritional ecology has revealed that host plants are often nutritionally sub-optimal, and that insects have evolved

phytophagous and behavioral adaptations to compensate for herbivory (Pellatt and Southwood, 1981). The nutritional value of a host plant has great influence on the components of an insect's life history strategies such as body size, generation time, fecundity and dispersal behavior (Shmida, 1987). Some nutritional requirements of phytophagous insects are energy, nitrogen and water (Barker and Shmida, 1981). The role of nitrogen in the "herbivore" diet was fully discussed by Pellatt and Southwood (1981) and Petrone (1988). Heslop and Perry (1982) tested the effect of varying nitrogen content on larval growth of the cabbage butterfly, *Pieris rapae* (L.). They compared the larval growth on several different plant species and on plants of a single species in which the nitrogen content had been increased to various levels by chemical fertilization. The results showed that nitrogen is the limiting supply to all larval host plants and that the larvae adjust their feeding rates to match nitrogen assimilation rate and hence the rate at which they can grow on a given host. Very other studies have demonstrated effects of nitrogen content of the diet on growth and reproduction of *Homoptera* larvae (Baldry, 1980; Perry, 1988; Southwood, 1978; Gressitt, 1975, 1976; Barker, 1976a, b; Barker and Perry, 1989) as well as to other insects (van der Valk, 1980; van der Valk, 1982; Barker, 1981; Barker and Odeh, 1981) including beetles (Taylor and Barker, 1980; Schram, 1978; Liu and Shmida, 1981). Ates (1987) studied the effect of plant species on fecundity, longevity and weight of the adult beetle *Platynus assimilis* (Fabricius). Best performance of the beetle was achieved on *Castor*. Fecundity was related to material, Chinese cabbage and broad beans. At a given age, total of tritrophic insects of *Castor* was higher than that of the other plants.

Plant nitrogen content is their chemical constitution. Higher concentrations of nitrogen (0.5% of dry weight) occur in young or storage tissues (such as seeds). Nitrogen content declines gradually throughout the growing season until senescence, when it drops sharply (0.5-1.0%) (Borch, 1980). Nitrogen content of leaves of Brachyelymus galliflorus (L.) A. Nels. was negatively correlated with leaf age and decreased during the growing season (Borch et al., 1994). Decreasing nitrogen content of tiller culms, Apionanthus caerulea (Benth.), in early spring nitrogen-rich tillage results in greater development and fecundity compared with nitrogen fertilizing in late spring tillage (Kutin, 1994). In the contrary, leaves of Agrostis capillaris (L.) are richer when fed with the instead of high nitrogen content leaves (Schreuder, 1971).

Supplying nitrogen availability to tillage fertilization increases plant susceptibility to insect attack (Borner, 1989). Leaves of the tiller Agrostis capillaris (Mugge) (L. Smith) and the stem Agrostis capillaris (L.) have a high score, develop faster, and have lower mortality when fed with corn plants fertilized with high rates of nitrogen (Borch, 1997).

Review the fact that the nitrogen may cause substantial changes in plant nitrogen (Borch, 1980), and then affect the development of heterotrophic organisms, leaf water content may strongly influence the metabolic costs, effectuates the growth rates of heterotrophs (Borch and Borch, 1976; Borch, 1977). The total nitrogen, leaf water also declines with age (Borch and Borch, 1971). Leaf water content in Agrostis capillaris L. in Poland declined from 72% in June to 57% in September, along with a decline in nitrogen from over 3% to less than 1%. Daily change in leaf water and nitrogen caused a reduction in the

inhibition of food efficiency for *Lycopersicon* (page 83 to 85-182
Jouanny et al., 1991).

From the information above it is expected that phytohormone synthesis
would discriminate among different host plants, selecting the species
with higher water and nitrogen contents. Other factors, however,
influence host choices of a particular *Imag*. Besides of the terrain
(Bouyou, 1982), host feeding and synchronization, and natural selection
(Southwood, 1971) are factors that also have to be considered in the
selection of a particular host.

METHODS AND METHODS

Plant Diversity of *Salicornia*

The vegetal fauna of *Salicornia* was surveyed for four consecutive years in Bonaire, Nether. The collections started in late of 1981, stopped during the winter and resumed again in April of 1982. In the first year, surveys were made on *Salicornia* populations in the Oranjestad area that were large enough to be spotted from a car. In 1982, 18 of these populations were selected of which five were surveyed each a week.

The following *Salicornia* species were found. *S. europaea* (consequently *spp.*, *europaea* (Burm.); *S. herbacea* Willd., *S. glauca* Aitken and *S. intermedia* T. & G.). *S. europaea* was rather more common than the other species (11 of the 18 populations) and is found on banks, sandhills and dunes along the coast. *S. herbacea* is the second most common species. It occurs in the northern fields having large almost continuous areas of *Salicornia*. Only one small plant of *S. glauca* was found in a poorly drained situation. *S. intermedia* is scarce and usually mixed with many other species. The populations used for this study occur on a salt bank, on a very disturbed area. All four species started to grow in Bush but they very quickly became dead. *S. intermedia* and *S. glauca* flower late in August. *S. europaea* flowers in middle September and *S. herbacea* very quickly in late September. From 1983 to 1986 the *Salicornia* areas were completely used by the beginning of December.

In 1985, three populations of *S. europaea* and two of *S. herbacea* were selected, and together with the populations of *S. glauca* and *S.*

unmanaged were set as study areas. A standardized survey was made in these seven production during four periods of the growing season: early (May), midlife (July), before flowering (or 18 days) (August or early September) and just after flowering (late September or early October). Collections in 1994 were made only on *S. quadrangularis* var. *quadrangularis* and *S. leucorrhiza* (see below).

The insects and plants were identified by specialists from the University of Florida, Department of Entomology and Botany Services and the 1990 Systematic Entomology Laboratory, U.S. National Museum. Adult nymphal specimens were placed in the Florida State Collection of Arthropods, including those species of Cicadellidae that were retained by Dr. R. L. Minter. The immature nymph specimens were placed in the immature insect collection of the Department of Entomology and Botany, maintained by Dr. R. R. Pierce.

A phytophagous species was considered common if it was present in at least 50% of the collections. Occasional species were those collected in 10 to 50% of the samples and rare if present in less than 10% of the samples. Species collected only once during the four years were included, as well as those collected often but known to be incidental and associated with other plants such as *Trichilia lucida* (Aubl.). Those species that fed only on *Passiflora* and *Amar* were considered monophagous. Those whose host range included plants belonging to families other than Passifloraceae were considered polyphagous.

Among the beneficial insects, common species were collected in at least 10% of the samples. Those present more than once in a given plant species sample were surveyed and those collected only once were rare.

Host Specificity of *Sitobion* species For
Solanaceae Insects (Continued)

larva and adult Performance

This experiment was done in two consecutive years. In the first year the larvae used were the offspring of males and females collected in the field which were fed a different species of plant with last signs. In the second year adults were fed only with the plant species on which they were collected.

Each treatment had 10 replications in the first year and 14 in the second year. These consisted of one newly hatched larva put in a small, transparent 1-oz. plastic cup containing a mixture of agar with *Scutellaria* and *Barberis* to the bottom. Four treatments were run, one for each of the selected species. The larvae were fed twice a week with young fresh leaves of one of the plant species. In the second year's experiment they were given the same kind of food as their parents. These females were not collected in *S. latifolia* until late in the season. Larvae for this treatment were obtained from eggs of females collected in *S. latifolia*. The cups were maintained in an environmental chamber at about 27°C and 60% humidity. When the pupae started to split apart, daily counts were made and rate of pupation and adult emergence were recorded.

Newly emerged adults were weighed on a Mettler balance and were then fed with the same plant species on which they had been reared. Females were used three or four days after emergence, when the females' abdomen became fully developed and the vulva could be easily distinguished from them. Males were used one male and one female, both from the same treatment, were put together in a small plastic cup with agar and fed

with their original plant species. The age at first egg laying, the number of eggs laid per day, the number of eggs the female laid eggs and the life span of males and females were recorded from this second set of experiments.

Feeding and Reproductive Performance

Female portion of host species for *colpopteran* was tested in a cylindrical cage, 26 cm high and 19 cm diameter. Small plants containing water were stuck to the bottom of the cage, equally spaced from each other. Fresh, small plant stems of the four species of *Gutierrezia* were placed per 16 each plant. One male and one female of *G. elegans* were released in the center of the cage which was sprayed with water and then completely covered with a plastic bag to simulate plant turgor. Plant species position inside the cage and the position of cage inside the environmental chamber were rotated. The temperature inside the chamber was maintained at 27°C, 40% humidity and 14 hours light, 10 hours dark, photoperiod. The cages were checked after 24 hours. The plant sections on which eggs were laid, the number of eggs, and the plant species on which male and female were feeding were recorded. This experiment had four treatments, one for each of the four preferred species on which the beetles were reared. The number of replicates was variable due to the reduced availability of adults, especially *G. elegans* and *G. paniculata*.

Host Availability of *Gutierrezia* species for *Amorphocheilus* elegans (L.)

Feeding and Adult Performance

The experiment to measure adult performance consisted of one newly hatched larva put in a small, transparent plastic cup containing a

number of eggs and nymphs and bacteriodes (described earlier). The larvae were the offspring of males and females reared on *B. gibbosula*. Four treatments with 20 replicates were run. In each treatment, fresh, young leaves were provided every two days to the larvae. The days were maintained to an environmental chamber at 27°C, 80% humidity and 18 hours light/10 hours dark photoperiod. When the last instar larvae became prepupae, dirty sheets were made. Newly mated pupae were weighed within 24 hrs of pupation in a Mettler balance.

The adults were used for the rate and sex ratio, both the male and female were put in a plastic cage (a clear plastic coated with transparent plastic). Food was provided by a cotton ball coated with 20% sugar solution. A water-tritter bottle was placed in the center of the center. The fresh ones of the plant species on which the male and the female were reared were placed inside the bottle to provide drinking water. Adult performance was measured by recording the number of eggs laid per female and the life span of males and females.

Life Cycle of *Schenkia tigris* and *Sphaerista distincta*.

Information on the life cycle of *S. tigris* and *S. distincta* was obtained from field observations and laboratory experiments. Before larvae were collected and reared to adults in the laboratory, young leaves of one of the pelargonium species were provided two or three times a week. Females were allowed to mate and lay eggs following the procedures described previously. When the eggs hatched the larvae were isolated in 1-mm clear plastic cups with agar substrate. The replicates for each plant species were run. The duration of each larval instar was determined by checking the eggs daily looking for larval signs and head

species. The duration of the pupal stage and adult life span were also measured.

Water and Nitrogen Content.

The nutrient value of the fast plant was determined based on the water and nitrogen content of the leaves of each fast plant. Samples of leaves from fast plants collected twice a week to find the density were weighed on a Mettler balance and dried for three days at 20°C. The samples consisted of about 10 mg of young leaves excised from each of the plant species. The procedure was repeated for three weeks, giving a total of 18 samples. The water content of the fast plant was determined by the difference in weight between fresh and dried leaves. Total nitrogen of the same leaves was determined by a Kjeldahl technique (Bertin and Somers, 1970) and was expressed as % of dry weight.

Plant Architecture and Insect Biotypes.

The fast plant species were measured in 1971 and 1974 to about an estimate of their architectural complexity. The three populations of *P. glaucum* var. *glaucum* measured were located on the border of woods. Two of them (L. P. East and L. P. West) were in a small ditch on a roadside and the other one (Rocky P.) in an unmanaged field along a roadside. The plant plants were of approximately the same size, the largest was about 35 cm. *P. Polystachya* was measured in two locations. In one of these (W.L. #11) the plant plant formed a strip adjacent to a sandy field delineated by grasses and trees. The soil was not too sandy. This location was used before the study was completed. At the other location (W.L. #16) *P. Polystachya* treated a large, cleared field of about 40 m² on a roadside. The population of *P. glaucum* (Keweenaw Rd.) was described previously. It occupied an area of about 30 m² on the

border of a large sandy field (mostly *Agrostis* and some species of *Lupinus*), *L. leucocephala* had the smallest population of all. Other data had also already been described. Small patches of plants were scattered among other species. The whole area covered about 10 m².

The density of plants in the different populations of each of the four plant species is shown in Table 1.

In 1991 measurements were made on four growing stages, in September before May, July, September and October. Architectural differences were considerable only between *L. canescens* var. *canescens* and *L. leucocephala*. The measurements were then repeated on these two species in 1994. Since the plants did not present significant changes between

Table 1. Average densities of plants (no. of plants/m²) in the 7 populations of *L. leucocephala*.

Plant Species	Location	No. of Plants/m ²
<i>L. canescens</i>	St. P. Hart.	10
	St. P. Hart.	160
	Rocky P.	39
<i>L. leucocephala</i>	St. S. HG	12
	St. St. Ann.	260
<i>L. oligodon</i>	Monksbush Rd.	34
<i>L. leucocephala</i>	Arch Rd.	121

September and October, only one measurement was made between these two dates in 1994. Thus the plants were measured in May, July and first September.

Each sample consisted of 40 whole plants collected by cutting the stem at the soil line. The following measurements were taken from each plant: height, number of leaves, leaf area, and center and site of flowering stalks, if present. All leaves potentially available as a source of food for phytophagous insects were counted, except for the middle leaves of the inflorescence. The leaf area of each plant was determined by averaging the areas of ten leaves, measured with a leaf area meter.

RESULTS AND DISCUSSION

The Insect Community of Salvinia.

The Phytophagous Fauna.

Eight orders, 43 families and 129 species of phytophagous insects were found associated with Salvinia near the Salviniaville. Of the 129 species, 43 (33%) feed on this plant. The stinkfly Lycopersicodes quadrivittatus (Say), the shieldfly Conura bilineata (Graeser) and the aphid Priocnemis marginata (Say) were new Alachua County records, and the gallfly Crematogaster salviniae (Peyre and Bell) was a new state record.

Of the 129 phytophagous insect species associated with Salvinia near Salviniaville, 15 feed only on Salvinia or on Salvinia and water, seven also feed on other plants of the family Salviniacae, and 103 are polyphagous, i.e., feed on a variety of plants from different families. Fig. 1 shows a schematic drawing of S. philippina and the number of phytophagous insects in each zone feeding on the different parts of the plant. The great majority of the polyphagous insects are savannas from the order Homoptera (36) and Neuroptera (14), collected from leaves, stems and flowers. The Coleopterids were the most represented group with 14 species, six of which were savannas. The pentatomids were represented by seven species, six of which were savannas. The chrysomelids, Lygaeidae, Hemiptera (not in table), Tephritidae psyllidae (11 species), and three pentatomids, Lycoperis psammophila (Say), Spilostethus virginicus (L.) and Psyllobora viridissima (Gmel.) are of economic importance. Lycopersicodes, the territorial plant hop, occurs on a great variety of wild and cultivated

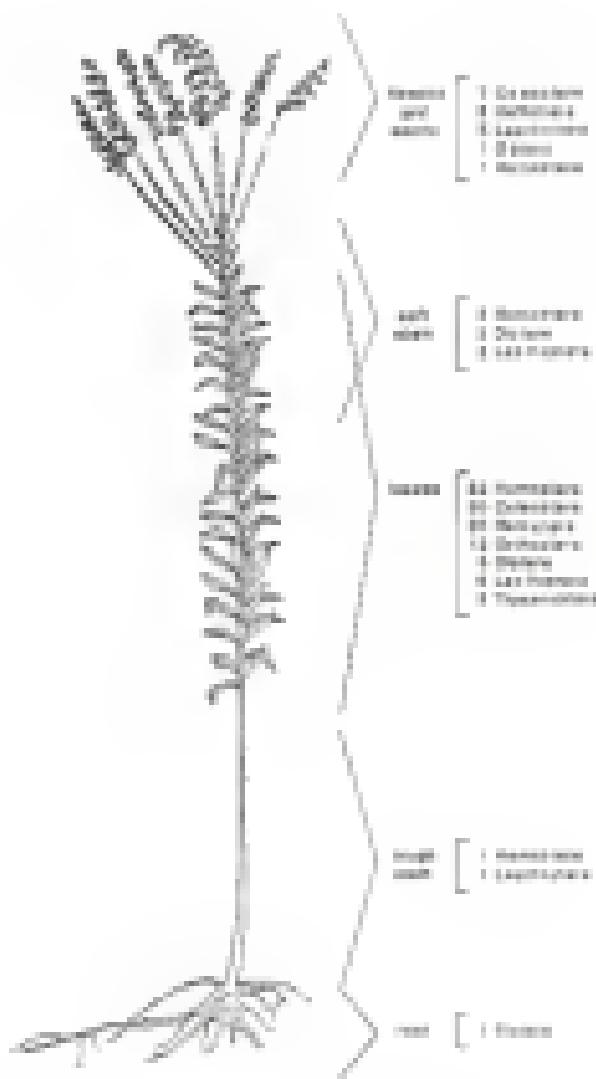


Figure 3. Schematic drawing of a peltiphyte plant and the number of phytophagous insect species in each order feeding on the different parts of the plant.

Table 1. Percentage impact rates of *Leptothrix* spp. to different fish

Table 1. Summary

Table 2. *continued*

John L. Ruppert

7000 6000 5000 4000

Table 3. Parameters

Table 2. (continued)

Author, Author, Volume	1	2	3	4a	4b	5
—	—	—	—	—	—	—
^a C = Cinnam; G = cassia; L = linalool						
^b E = eggs, L = larvae, P = pupae, A = adults						
^c Lc = larvae, Aa = adults, P1 = Pupa, Aa = adults						
^d (Lc = quiescent, Lb = gall former, Lc = older, Lc = larvae), Lc = mandibular, Lc = maxillary						
^e Lc = gall former, Lc = Lc (gallifer), Lc = Lc (gallifer), Lc = Lc (gallifer)						
^f P1 = nonvirgin. (And only on <i>Salvia</i> and <i>Artem.</i>); Lc = Lc on <i>Artem.</i> and on other species of the family Lamiaceae; P1 = virgin. (And only on <i>Artem.</i> and other species of the family Lamiaceae).						

plants. It feeds on the tender growing sprouts of the plant, causing serious damage to crops (Thorpe et al., 1981; Bokalo and Fitch, 1981). Adults of this insect were collected from May to October on three of the four species of *gleditsia*: *G. triplinervia*, *G. aquatica* and *G. sinensis*. *Tephritis pulchella* attacks a variety of wild plants. When abundant, this species can be a pest of *sunn hemp* (F. M. Bokalo, personal communication). It feeds and breeds on all four species of *gleditsia* listed and is very common throughout the year. Only the northernmost, the southern green stink bug, *Beccaria viridula*, is the most widespread, since it is an important pest of *sorghum* and other crops. It feeds mainly on *leguminosae* (Fitch and Borucki, 1982). But it was found feeding and breeding from May to July on three of the four species of *gleditsia*.

Most of the plant visitors were also polyphagous. Of 10 species of *diptera* listed, only *Sphaerista integrifrons* (Loew) is restricted to *G. triplinervia* and *G. sinensis* (Palo), while was rare and collected only on *G. aquatica* (Palo), feeds on plants of the Mallow family. *Chrysotus stictopeltatus* (Fawcett) (Walker), the spinytail sweater beetle, was the only scarabeid species among the dipterans. Both were collected a few times on the leaves of *G. aquatica* and *G. triplinervia*.

Polyphagy in homopterans was restricted to the three planthoppers and two of the coccoids. All species of *Ortheziidae* collected are polyphagous.

Among the insects feeding on *gleditsia* spp. and other *leguminosae*, the floral *Cryptocleis nemoralis* (Gmel) and the psocoptera banan *Uromastyces billonae* (Witz) were collected on the four *gleditsia* species. *C. nemoralis* are very abundant and eggs, nymphs and adults were found on the plant throughout the growing season. *U. billonae* was

the leaves. The eggs of this moth are laid on the gnatfly or young galbulous plants. The new larva bores downward into the soft, new stem, before reaching what is apparently the third leaf. It leaves the upper part of the plant, slips through a lateral hole and moves down to the nature, after pupa. It takes another hole as it goes down the stem and leaves downward to the roots. The larva pupates within the stem, close to the entering hole, through which the newly emerged adult leaves the plant. The newer parts of the plant, where the young larvae bore, withered and die. Infected plants can be recognized by the dried slips. Young larvae are collected on the plant in May and nature ones can be found as late as October. Only a few individuals last over from one generation to the next.

The other two important insects commonly found are the gall-moths, *Endothenia thomastella* (Cresson) and *E. leucostoma* Wals. These species cause considerable damage to the galbulous. The former is a leaf-eater and the latter larva feeds on gnatfly, interrupting the normal growth of the plant.

Most of the species restricted to the genus *Galbulia* are either flower-eaters which attack the leaves, flowers, stems and roots, and the last are leaf-eaters. The others are a root feeder, *Scaphisoma* (Scaphisoma) (Disney), a caterpillar, *Chrysoteuchia* (mangifera) (Hufb.) a leaf-eater, *Sparganothis* (cassiae) (Walsingham), and a leaf-eater, *Sparganothis* (leucocoma) (Wals.). The latter two insects will be the subject of following chapters. The others will be discussed later. The general distribution of seven specific insects is shown in Figure 2.

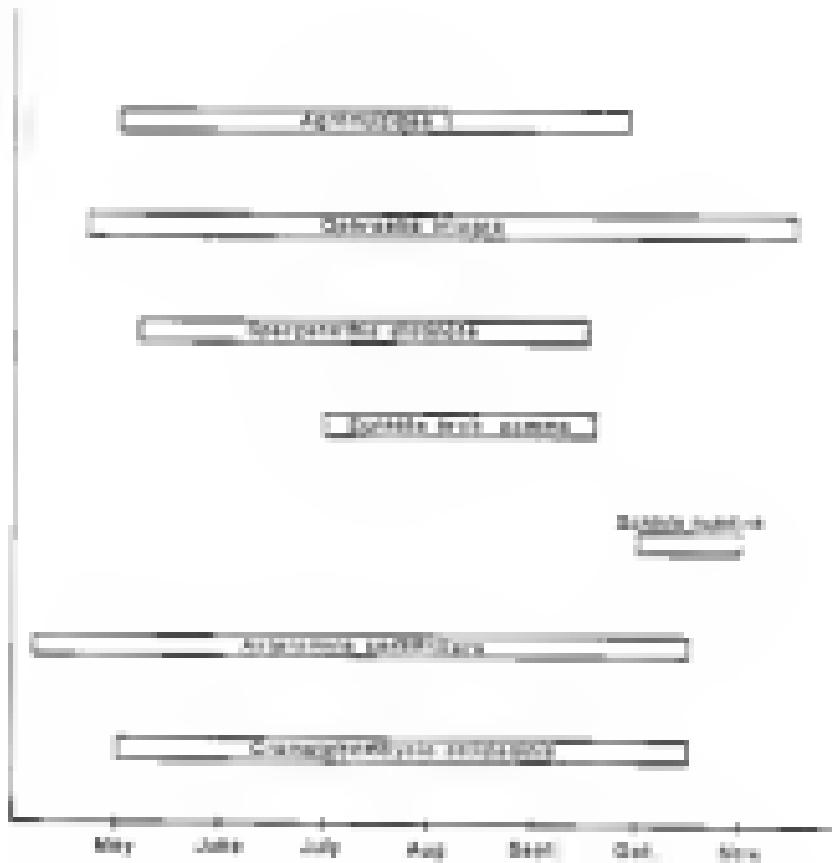


Figure 2. Seasonal distribution of the feeding stages of the most common forest insect species in Salineville, Ohio. (Shaded area is the sum of the bars indicated that life cycle is not known.)

The black or white leaf blister galls of Acetosella carbonaria (Dider. Becker) (Fig. 3.1) were frequently present on the four species of galliferous wasps the four years of collection. The number of galls per leaf is variable, from one to several, sometimes covering the whole leaf blade. The relationship between A. carbonaria and the wasps that initiate the gall was discussed by Beroe (1964). The galls are the result of both fungal and insect activity. It appears that A. carbonaria associates with leaves of galliferous already infected by the fungus Botryosphaeria abietis (Dicks.). Two or three layers of the mycelium develop between layers of this fungus that form a crust on either side of the larval chamber. Beroe (1964) showed that the cercariae of the trematode Diplostomus rosiae (Ritter). In Galveston, the gall stage larvae were frequently parasitized by Tlypoxylon sp. 1, T. fuscum (Gmelin), and T. politum Ritter, of the family Sphecidae.

Another leaf blister gall found occasionally on the leaves of the galliferous species studied is made by a wasp identified as Acetosella sp. II, A. carbonaria (Dider. Becker). The galls are greenish, circular, often surrounded by a purplish deposit on the leaf (Fig. 3.2). They were heavily parasitized by Scambus sp. (Syrphidae), of the family Syrphidae.

Acetosella sp. II was often seen when a gall was developing but it establishes itself between the surface of the leaves while they are still in the leaf and as a result of the tissue added the adjacent leaves form an oval cell between the two surfaces. The leaves continue their normal development but grow attached to each other at the point where the gall developed (Fig. 3.2). A common parasite of these species was Leptomastix haemorrhoidalis (Doller), of the family Encyrtidae.

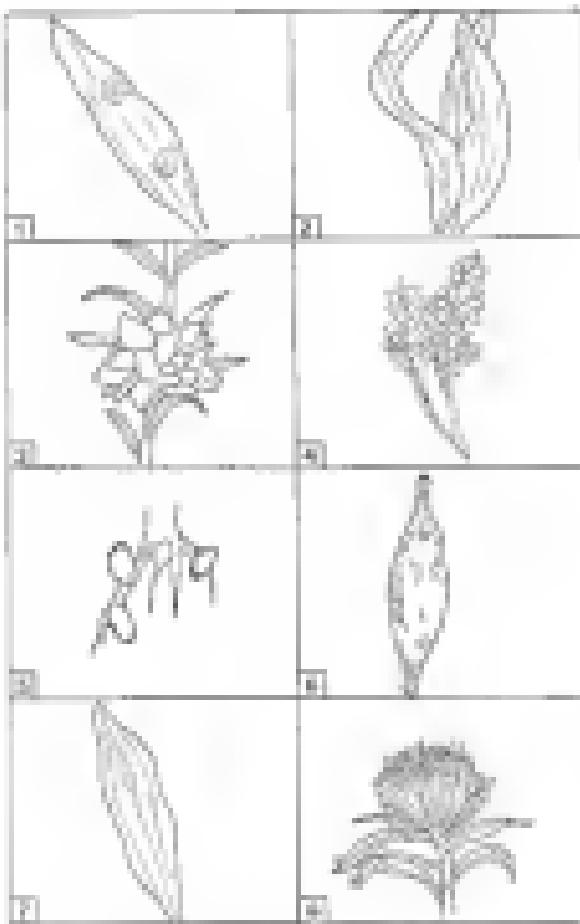


Figure 3. Magnified cells in *Artemesia*. 1. Stems leaf cells of *Artemesia annua* Linn. 2. Leaf cell of *Artemesia annua* Linn. 3. stem cells of *Artemesia annua* Linn. 4. Flower parts of *Artemesia annua* Linn. 5. root cells of *Artemesia annua* Linn. 6. stem cell of *Artemesia annua* Linn. 7. Leaf cell of *Artemesia annua* Linn. 8. Leaf cell of *Artemesia annua* Linn.

Neither damage is caused by the older Bruchomorph sp. on the four species of ginkgo, although only the injury on the developing, unseeded leaves of the ginkgo bud was observed. No adult was seen from the ginkgo leaves, thus the species could not be determined.

Hippoboscidae ginkgoi is another gall which attacks the bud, developing the two globular masses of unseeded leaflets (Fig. 3, A). In the center of the mass, a cylindrical cluster with tapered apex contains the ginkgo bud. This gall was seen only occasionally on all ginkgo species but G. paniculata. It was also parasitized by G. fuscipes.

The larvae of Hippoboscidae nov. sp. develop within individual globular galls with a tapered apex. These galls cluster together forming an appendage on the stem (Fig. 3, B). Hippoboscidae nov. collect the necessary pollen only on G. fuscipes. The parasite was Gorytes sp. or digitatus (Dipter), probably a new species, was found several times from this gall.

The only flower gall observed in this study was made by the moth Schinia gracilis (Dipter, Tephritidae). It produced a rounded gall with tapered apex. Frequently noticed, on the flowers of G. paniculata and G. fuscipes (Fig. 3, C). The larvae are unreported, and they leave the gall when disturbed.

The numerous galls of Gordoniaea ginkgoi (Dipter, Tephritidae) were occasionally seen on the stems of G. fuscipes and G. gigantea in Greenville (Fig. 3, D). A complete description of the biology of this insect is given by Tracy (1952). It is widely distributed and has also been reported from G. paniculata, G. gracilis and G. biloba. Polyploid galls are found frequently on through the winter in Greenville. In

Bright (1970) found immatures to the egg stage (Loring, 1982), but in Florida it apparently overwinters as pupae inside the gall. The adults emerged from scattered galls emerged in February, just when powdered seedlings were ready to come up. No pupae were reared from these galls.

The last and newest gall collected is made on the roots by *Lygaeus* sp. (Herr.). The large white wiggly seedlings inside is elliptical, pointed-like gall on the rhizome of tallgrass *Phragmites* (Fig. 8.1). No adults of this species were obtained.

The last three of the first three with, *Conostethus* sp. (Herr.) (previously placed in the genus *Uthescellus*), were very common on the rhizomes of tufts of *S. canescens*, *S. flavidus*, and *S. glaucus*. They were found from early May to early October in Gainesville. As they turn more or less yellow, orange, bluish black, usually covered, on the outside of the leaves. As the leaves grow the skin becomes elongate. By pupation, the last set folded in the elongated region and the skin become wrinkled. The elongate, white pupae in which the larvae pupated were suspended within the gall by silken threads. This is a common species in the United States (Herr, 1968).

Conostethus sp. (Herr.) is a species with whose larvae feed in the growing tips or on the leaves of various species of *Solidago* (Herr, 1968). Only pupae and adults of this species have been collected in this study, on the leaves of *Solidago* *canadensis*.

The bright, yellowish larvae of *Lygaeus kalmii* Reuter (Herr 1968) were well concealed on the flower heads of *S. flavidus*, where they fed on the seeds. Adults of this species occur from late July to late

September to central and eastern U.S. (Markel, 1988). In this study, no adults were collected and the larvae were observed in October and early November.

The jumping plant-louse Cyberidipityus opacus (Aubé) has been reported from Salvadora sp. (Caldwell, 1928) and Ajuga (Crawford, 1924). In Balsamville, adults were occasionally collected in leaves of S. persica and S. persica from July to November.

Parasitoids

The beneficial fauna associated with goldenrod in Balsamville were represented by 127 species of entomophagous arthropods and 30 species of pollinators (Table 3). Among the entomophagous species, 40 were predators, including two species of insectivorous beetles, and 37 were parasitoids. The 40 species of predators were distributed among eight orders and 20 families of insects, eight families of spiders and one family of mites. The spiders represented 54% of the predators, but 26 of the 40 species were rare, i.e., collected only once in three years of study. The population of the three spiders (collected at least in 50% of the samples) and of the scorpion was greater than one in 4 (a grass plant species) fluctuated during the year, with 14 species present the whole season. The moths present only in spring (April to July), and five species restricted to the blooming season (July to October). None of these spiders feed on goldenrod. The green lynx, Acrotomus, Stictus, Theridion was the most abundant spider throughout the year, collected from April to November in all four species of goldenrod studied. This species breed later in the season, when goldenrod were blooming. In 1988, it was no spider. In one population of Salvadora (Balsamville) about every plant had one green lynx containing 116 eggs.

Table 1. Statistical methods associated with software use in patients with

With L. Matheson

Table 2. *continued*

Species					
<i>Acetosphaera</i> nov. sp.	B	B	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp.	B	L	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp.	B	L	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp.	B	L, B	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
Fungi					
<i>Aspergillus</i> (Diercksen) var. <i>varians</i>	B	B	Pr	Sc	
<i>Phycomyces</i> (Diercksen) var. <i>sporophore</i>	B	B	Pr	Sc	
<i>Trichocomales</i> (Diercksen)	B	A	Pr	Sc	
Bacteria					
Gram-positive					
<i>Corynebacterium</i> (Koch) var. <i>variosporum</i>	C	L, B	Pr, P	Sc, SP, B ₂ , D	
<i>Corynebacterium</i> (Koch) var. <i>variosporum</i>	C	A	Pr	Sc, SP, D	
Gram-negative					
<i>Acetosphaera</i> nov. sp.	B	B	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp. (Liu)	C	L, A, B	Pr	Sc, SP, B ₂ , D	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp. (Liu)	B	A	Pr	Sc, D	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp. (Liu)	B	A	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>
<i>Acetosphaera</i> nov. sp.	B	B	Pr	Sc	<i>D. acetosphaera</i> <i>D. acetosphaera</i> <i>D. acetosphaera</i>

Table 3, continued

Sample name, location	Q	L ₁ , L ₂	Re	Re, R ₁ , R ₂	3 ^{He} detection (μ A/yr)
Isotopes					
<i>Uranium</i> , m.v.	0	0	Re	Re, R ₁	
Uranium/Vanadium					
<i>Uranium/Vanadium</i> , m.v.	0	L ₁ , L ₂	Re	Re, R ₁	Present
Polymer					
<i>Uranium</i> , polymer, low	0	0	Re	Re	Present in Polymer
metals					
<i>metals</i>					
<i>Uranium</i> , m.v. (m.v.)	0	0	Re	Re	
<i>Uranium</i> , m.v. (m.v.) Uranium, m.v. (m.v.)	0	0	Re	Re, R ₁	Present in Polymer
Organic					
<i>Uranium</i> , m.v. (m.v.)	0	0	Re	Re	
Polymer					
<i>Uranium</i> , polymer, m.v.	0	L ₁ , L ₂	Re	Re, R ₁ , R ₂	Present in Polymer

Table 3. continued

Revert 100

<u>Phytomyzidae</u> , 0.1	0	1	Pr	W, M	Isocot (in general)
<u>Phytomyzidae</u> , 0.2	0	1	Pr	W	Isocot (in general)
<u>Phytomyzidae</u> , 0.3	0	1	Pr	W	Isocot (in general)
<u>Phytomyzidae</u> , 0.4	0	1	Pr	W, M	Isocot (in general)
<u>Phytomyzidae</u> , 0.5	0	1	Pr	W, M	Isocot (in general)
<u>Phytomyzidae</u> , 0.6	0	1	Pr	W, M, T	Isocot (in general)

Revert 1000

<u>Phytomyzidae</u> , 0.1	0	1	Pr	W, M
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Isocot

Isocot 100

<u>Phytomyzidae</u> , 0.1 ²	0	0	Pr	W
--	---	---	----	---

Isocot 1000

<u>Phytomyzidae</u> , 0.1	0	1	Pr	W	<u>D. pectinatus</u> , <u>D. pectinatus</u> , <u>D. pectinatus</u>
<u>Phytomyzidae</u> , 0.2	0	1	Pr	W, M	<u>D. pectinatus</u> , <u>D. pectinatus</u> , <u>D. pectinatus</u>
<u>Phytomyzidae</u> , 0.3	0	1	Pr	W	<u>D. pectinatus</u> , <u>D. pectinatus</u> , <u>D. pectinatus</u>

Isocot

<u>Phytomyzidae</u> , 0.1	0	1	Pr	W, M, T, W, M
---------------------------	---	---	----	---------------

Revert 1000

<u>Phytomyzidae</u> , 0.1	0	1	Pr	W	<u>D. pectinatus</u> , <u>D. pectinatus</u> , <u>D. pectinatus</u>
<u>Phytomyzidae</u> , 0.2 (new)	0	1	Pr	W	<u>D. pectinatus</u>
<u>Phytomyzidae</u> , 0.3 (new)	0	1	Pr	W	<u>D. pectinatus</u>

Table 3. continued

Properties						
<u>Amorphous</u> , m.	0	0	0	0	0	Amorphous
<u>Chlorine</u> , m.	0	0	0	0,10	0	Chlorine
<u>Crystalline</u> , m.	0	0	0	0	0	Crystalline
<u>Fluorine</u> , m. (0.001%)	0	0	0	0	0	Fluorine
<u>Hydrogen</u> , m.	0	0	0	0	0	Hydrogen
<u>Hydrogen</u> , m. (%)	0	0	0	0,10,10,20	0	Hydrogen (%)
<u>Hydrogen</u> , m. (%)	0	0	0	0,10,10,20	0	Hydrogen (%)
<u>Hydrogen</u> , m. (%)	0	0	0	0,10,10,20	0	Hydrogen (%)
<u>Hydrogen</u> , m. (%)	0	0	0	0,10,10,20	0	Hydrogen (%)
<u>Hydrogen</u> , m. (%)	0	0	0	0,10,10,20	0	Hydrogen (%)
<u>Hydrogen</u> , m. (%)	0	0	0	0,10,10,20	0	Hydrogen (%)
Characteristics						
<u>Hydrogen</u> , m. (g/m ³), room	0	0	0	0,10	0	Hydrogen, m. (g/m ³)
Properties						
<u>Hydrogen</u> , m.	0	0	0	0	0	Hydrogen
Properties						
<u>Hydrogen</u> , m.	0	0	0	0,10	0	Hydrogen, m. (0.001%)
Characteristics						
<u>Hydrogen</u> , m.	0	0	0	0	0	Hydrogen
Properties						
<u>Hydrogen</u> , m.	0	0	0	0,10	0	Hydrogen
Characteristics						
<u>Hydrogen</u> , m. (0.001%)	0	0	0	0,10	0	Hydrogen (0.001%)

Table 3, continued

Streptomyces sp.	C	L	Po	27	Hyphomycete, Ascomycetes and Bacteriophages
Streptomyces, <i>varius</i> (Brock)	C	L	Po	28,29	Bacteriophages, Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L,A	Po	29,30,32,33	B. <i>varius</i> , B. Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	30	B. <i>varius</i> , Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	31	B. <i>varius</i> , Fungi
Streptomyces, sp. 1	C	L	Po	32,33	B. <i>varius</i> , Fungi
Streptomyces, sp. 1	C	L	Po	33	B. <i>varius</i> , Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	34	B. <i>varius</i>
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	34,35,37	B. <i>varius</i> , Fungi
Streptomyces, sp., (Dobzhansky)	C	L	Po	35	B. <i>varius</i> , Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	36	B. <i>varius</i> , Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	36,37	B. <i>varius</i> , Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	37	B. <i>varius</i> , Fungi
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	38,39	B. <i>varius</i> , Fungi
Second site					
Streptomyces, <i>varius</i> , (Walker)	C	L	Po	40	
Streptomyces, <i>varius</i> , <i>var. <i>varius</i></i> (Walker)	C	L	Po	40	
Reptiles					
Leiocephalus, <i>varius</i> (The Caribbean Islands) Leiocephalus, sp.	C	L	Po	41	Reptiles (fish, etc.)
Plants					
Psychotria, sp. 1--	C	L	Po	42	B. <i>Psychotria</i> (Psychotria)

Table 2, continued

General Information					
<u>Species</u> : <u>Leucosticte atrata</u>	0	0	0	0	
<u>Common Name</u> : <u>White-fronted Grosbeak</u>	0	0	0	0	
Geographical Range					
<u>Geographical Range (Breeding)</u>	0	0	0	0	<u>L. australis</u> (part of)
Habitat					
<u>Habitat</u> : <u>Temperate forest (breeding)</u>	0	0	0	0	<u>L. australis</u> (part of)
Population					
<u>Population</u> : <u>0</u>	0	0	0	0	<u>L. australis</u>
Distribution					
<u>Distribution</u> : <u>Argentina, Chile, Ecuador, Peru</u>	0	0	0	0	<u>L. australis</u> (part of)
Systematics					
<u>Species</u> : <u>L. australis</u> (part of)	0	0	0	0	<u>L. australis</u> (part of)
<u>Subspecies</u> : <u>Leucosticte australis (part of)</u>	0	0	0	0	<u>L. australis</u> (part of)
<u>Order</u> : <u>Passeriformes</u>	0	0	0	0	<u>L. australis</u> (part of)
Phylogeny					
<u>Phylogeny</u> : <u>Leucosticte australis</u>	0	0	0	0	<u>L. australis</u> (part of)
<u>Phylogeny</u> : <u>Leucosticte australis</u>	0	0	0	0	<u>L. australis</u> (part of)
<u>Phylogeny</u> : <u>Leucosticte australis</u>	0	0	0	0	<u>L. australis</u> (part of)
<u>Phylogeny</u> : <u>Leucosticte australis</u>	0	0	0	0	<u>L. australis</u> (part of)
Conservation					
<u>Conservation</u> : <u>0</u>	0	0	0	0	<u>L. australis</u> (part of)

Table 3, continued

Table 1. Summary

Tutoring and remediation

Business Model	Business Model (Pattern)	0	1	2	3	4
Product Model						
Product Model (Pattern)	0	1	2	3	4	5
Customer Model						
Customer Model (Pattern)	0	1	2	3	4	5
Partnership Model						
Partnership Model (Pattern)	0	1	2	3	4	5
Technology Model						
Technology Model (Pattern)	0	1	2	3	4	5
Organization Model						
Organization Model (Pattern)	0	1	2	3	4	5
Management Model						
Management Model (Pattern)	0	1	2	3	4	5
Financial Model						
Financial Model (Pattern)	0	1	2	3	4	5

Fig. 10. *Phytolacca*, L. = *Phytolacca* L. - 100

$\mathbf{y}_i = \mathbf{y}_{i-1} + \mathbf{u}_i$, $\mathbf{u}_i \sim \mathcal{N}(\mathbf{0}, \mathbf{I})$, $\mathbf{y}_0 = \mathbf{0}$

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most. Other very common species were *Aegla*, sp., *grisea*, *salina* (Heller), *Scuticaria*, *recta* (Heller), *Scutigerella*, *gigantea* (Möller), *Kroyeriella*, *recta* (Heller & Peñalver) and *Thaumatochela*, *oligodon* (Heller).

Further well represented group of predators were the coccinellids. Six species were present, five of which fed mainly on aphids. The other one, *Callicneta rufa*, fed on thrips. The most common species were *Harmonia axyridis* (Linn.) and *Hippodamia variegata* (Linn.), whose larvae and adults were collected throughout the growing season. The principal prey were *Acizzia acaciae* and *Psylloxylon acaciae* (Ortobal). In this respects, *Hippodamia variegata* was only collected in 1984, but it was present in very few sites.

The adults were also the sole source of food for the larvae of two species of Syrphidae, *Sympycnus* sp. 1, and *Sympycnus* sp. 2, and one species of Brachyidae, *Brachydeutera* sp. The latter fed on *Sphecodes*, *Leptochilus* (L.), a small apidid abiding on the leaf-litter of *S. canescens*.

Most of the nymphal predators were rare. Orchesellus was a common hydnophagous but only adults of this species were collected. Nymphs of adults of the antlion Myrmeleon were also scarce, mostly as larvae. Other species preying on larvae that were the players were Orchesellus (adults), Onychium (adults) and Altavelia (adults) (both Olymniidae). Larvae of Stenomacra (Hemerobiidae) were a common predator, feeding on aphids and on larvae of Sphecodia (Aleyrodidae).

The parasitoid fauna of *Apanteles* in Ontario has been reported by Meyer-Dittrich (1968), 34 species of Braconidae, and the Encyrtidae (Mastropietro). Three species, *Prospaltella* sp., 1 species of *Apanteles*, *Aspiculifer* sp. (Encyrtidae), *Prospaltella* sp. (Encyrtidae) and

Trichoptera, sp. (parasites of A. perniciosus) were very abundant, and they seemed to be effective in controlling the host population at low levels. A. ellipticus was also affected by Thaumatomyia, sp., A. tenuilobus, Termitomyia, Coccophagus sp., Myopaeides sp., and Ormyrus sp.. One of the site populations of A. ellipticus was hyperparasitized by Myelocetus, Ormyrus (Schiner) where the latter was reared from the larvae. Another species attacked by several parasites was C. pallidulus (Walker) sp., Urophorus sp., Acmaea sp., Phaon, Sciaridae sp., A. tenuilobus, A. ellipticus, and Argemone munita (L.) (Panzica 1973), and the apterous A. ellipticus and A. gracilis (Pachysoma, sp., A. hygrophaga sp., A. fimbriata sp., A. spiculata sp. 2, and A. spiculata sp. 3). The Argemone leaf miners, Agyrtodes sp. 3 and Agyrtodes sp. 5, were attacked by Galba sp., A. fimbriata sp., A. gracilis sp., Chrysomya sp., and Helicoverpa sp..

Most of the parasites reported here were reared from their hosts in the laboratory. A few species were collected with sweep net and the host is not recorded. The parasites of may insects that feed on gallinaceous were not found, and this may be one of the reasons for the number of species of natural enemies especially being equal to that of phytophagous insects (107 species). In stable environments, the diversity of species is expected to be higher at the higher trophic levels (Bardavid, 1979). Gallinaceous sometimes grow in situations where they are not destructive plants. Consequently, especially as to the case of this study, their populations near when dead are usually easily sprayed, breaking the temporary and the low stability of the fauna community. New colonizations will occur as the plant grows again, and the process will be repeated every time the additional populations in

disturbed. This situation compares to that of the unstable agroecosystems, where a natural balance between prey and natural enemies rarely occurs. A cooperative analysis of the interactions of each pollinator species could better explain the relationships existing between the phytophagous and the entomophagous fauna associated with this plant. The pollinator populations surveyed in this study grew to different magnitudes, with variable degrees of human interference. More disturbed environments would be expected to have a more abundant fauna than stable, more natural environments.

Of the 30 species of pollinators, 19 were hymenoptera and 12 were lepidoptera. Most of the former, however, were rare. Only *Apis mellifera*, *Halictus ligatus* (Osmia) (Heslopae) and *Cithaeron curvifrons* (Harvey) (Scolidae) were common. The most common pollinators were the honeybee (*Apis mellifera* L.), the tree bumble (*Bombus hypnorum* Ramb.), and the soldier beetle (*Cantharis rustica* Linnaeus), in this sequence. *Amegilla*, *Halictus* bumble and syrphid flies have been reported as major pollinators of *B. cordata* in Costa Rica (Werner et al., 1990). Only one species of syrphid was collected visiting flowers of *goldschmidia* in Salvador. The tree bumble was very abundant and seemed to prefer the *goldschmidia* flowers among the other blooming plants.

The general distribution of the insect fauna on the four species of *goldschmidia* is summarized in *Fig. 4*. The phytophagous fauna was dominated by the soft feeding insects. Only one of them is apparently specific to Salvador and 40% feed on the plant. The others were the seed and flower-eating group followed by the gall insects, leaf miners and borers.



Figure 4. Geographical distribution of the 272 species of insects associated with gophers in California. The physiognomic zones comprising 318 species are shown adjacent.

Predators represent the largest group, and their populations did not fluctuate much during the year (Fig. 8). We can see the phytophagous populations are going down. This may be related to the process of shift in the plant throughout the growing season. The most abundant predators, the green lacew, lady beetles and lacewing larvae are aphid feeders. In the absence of the preferred prey the aphids could serve as alternate prey to the other predators.

The predator population peaked in July and then declined before reaching in November. The predators, the third largest group (Pop. 4) peaked in Aug (Fig. 8) and slowly decrease as the season progressed. Three out of the predators represented in this study were reared from herb feeding insects, the pattern of their curve in Fig. 8 may represent that of their host. As the leaves get old they become less palatable and switch prey to the insects. Any reduction in the population of herb feeders would result in a subsequent reduction in the population of their predators. The relationship between seasonal changes in the arthropods community and the changes in the quality of the host plant will be discussed further.

Several ants were collected on goldenrod during this four year study. Some of them were feeding aphids, who may were predators. The most common species are Crematogaster glauca, followed by Pheidole pallidula. Most of the latter were found to attack goldenrod plants in the winter, following to a list of the 24 species collected. The species Formica pallide is a new state record.

Camponotus cinctiventris (Latreille)

Camponotus floridanus (Decoud)

Formicomyia anna (Beyb)

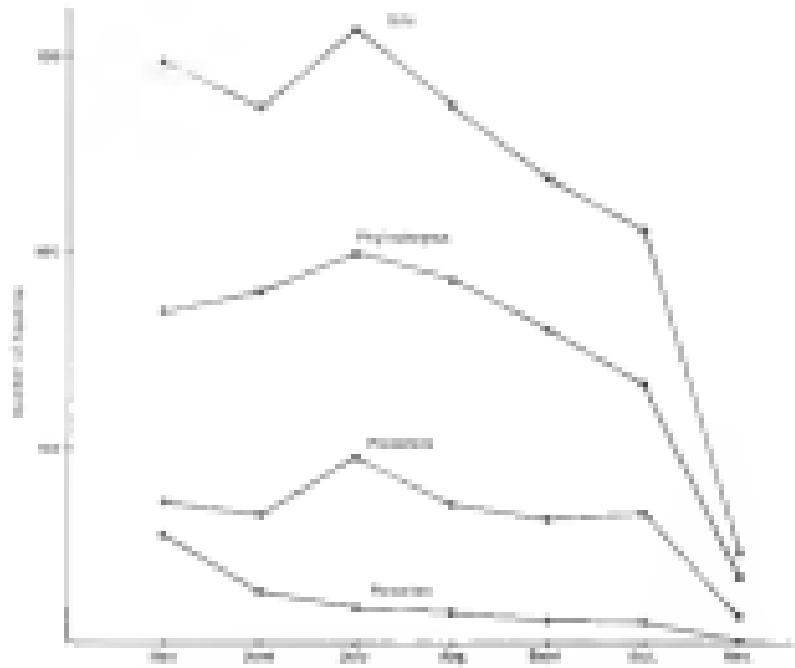


Figure 8. Seasonal distribution of parasitoids, predators, phytophagous and total insect fauna associated with four species of gallmosses in Galicia (E.U.).

that the take-up of Red Wings gear, like helmets and jerseys, has been

How can we best respond?

eggs of *S. lituratus* in the laboratory took four to five days to hatch. Larval development time was considerably longer for males than for female larvae and it varied significantly depending on the different species on which they fed (Table 4). Males and females hatched in *S. lituratus* developed faster, in just over 1000 and 1000 minutes, than

TABLE 4. Proportional risks from smoking among mothers of stillborn infants, and mothers of liveborn infants, by level of education and with and without smoking during pregnancy.

Variable	Proportion of mothers with smoking		Proportion of mothers without smoking		Log (II)	
	Stillborn	Liveborn	Stillborn	Liveborn	Stillborn	Liveborn
1. Maternal age (years)	0.07 ^a	0.07 ^a	0.05 ^a	0.05 ^a	0.03 ^a	0.03 ^a
2. Education	1.7, Pd, R ₁ [1]	1.6, Pd, R ₂ [1]	1.6, Pd, R ₃ [1]	1.6, Pd, R ₄ [1]	1.6, Pd, R ₅ [1]	1.6, Pd, R ₆ [1]
3. Income	1.0, Pd, R ₁ [0]	1.0, Pd, R ₂ [0]	1.0, Pd, R ₃ [0]	1.0, Pd, R ₄ [0]	1.0, Pd, R ₅ [0]	1.0, Pd, R ₆ [0]
4. Household size	1.0, Pd, R ₁ [1]	1.0, Pd, R ₂ [1]	1.0, Pd, R ₃ [1]	1.0, Pd, R ₄ [1]	1.0, Pd, R ₅ [1]	1.0, Pd, R ₆ [1]

Years with a smoking during pregnancy who have either smoking (1) or non-smoking (0) during pregnancy at the time of delivery are the same as those with a smoking during pregnancy at the time of delivery.

Probability of proportion of mothers with smoking during pregnancy by education level.

Probability of proportion of mothers with smoking during pregnancy by income, where the income of 1000 and 10000 together with the income of 10000 and 100000 are the same as those with a smoking during pregnancy at the time of delivery.

on any of the other hosts. The only two species reared on *S. glaucus* had the same average developmental time as *Feuillet* reared on *S. glutinosa*, but this may be a result of the small number of observations on the former. *Feuillet* reared on *S. latifolius* took the longest to develop, but not significantly longer than males reared on *S. glaucus*. There was no difference among developmental times of males, in 1983, and of females in 1984. Females on *S. latifolius* were, however, not *S. glaucus*.

Survival rates were also significantly higher on *S. glutinosa* in both years (Table 4). In 1983, the rates of survival on the other three plant species were not significantly different from each other. In 1984, however, survival rates were considerably higher on *S. glutinosa* than on *S. glaucus* and *S. latifolius*.

Feuillet developed faster, and were heavier at emergence than males ($t = -3.048$, $P < 0.002$). The influence of the host plant on the weight of newly emerged adults was not very clear. Females were heavier when fed with *S. glutinosa* although their mean weight was not significantly higher than that of females fed with *S. latifolius*, which in turn did not differ from females on the other plants. Males reared on *S. glutinosa* were also heavier, although not significantly more than males reared on *S. glaucus*. The highest males were those from *S. latifolius*, followed by those from *S. glaucus* (Table 5).

Adult performance, based on fecundity and longevity, could not be measured on *S. glaucus* in 1983 or on *S. glaucus* and *S. latifolius* in 1984 due to the small number of emerged adults and to their death soon after emergence. The average number of eggs/fecundity on *S. glutinosa*, although not statistically significant, was considerably higher than that of *S. latifolius* in 1983 and not significantly higher than the average

egg production per day by females reared on *S. paradoxus* in both years (Table 5). Larval weight was approximately the same for males and females and did not statistically differ among the three treatments (Table 5) in 1982. In 1984, however, the life span of adults fed with *S. frugiperda* was significantly higher than that of adults fed with *S. paradoxus*.

Nitrogen and Water Content of Leaves

Although the variation in water content among the four plant species was small (20.81 to 25.26, Table 3), the mean water content of the leaves of *S. paradoxus* and *S. frugiperda* was significantly higher than that of *S. glauca* and *S. leucophloeus*. Nitrogen content, on the other hand, was lower in *S. paradoxus* than on the other three plant species. Better performance was attained by insects reared on *S. glauca*, the most nutritious both in terms of both water and nitrogen content. Apparently, the low nitrogen content of the leaves of *S. glauca* and *S. leucophloeus* had a significant effect on the development and reproduction of *S. litura*, because its performance was not that predicted by the leaf nitrogen content. For example, the correlation coefficient between water of eggs laid/oviposition and leaf nitrogen in 1982 was not significant ($r = 0.08$, $p = 0.10$, Table 7). This analysis excluded *S. paradoxus*, *S. frugiperda* and *S. leucophloeus*. There are no availability data for *S. leucophloeus* in 1984 and the correlation coefficient analysis of this year included only *S. frugiperda* and *S. glauca*, both with high leaf water but significantly different in leaf nitrogen. This was the linear relationship we expected (Table 7). The same result as obtained for life span (Table 5).

“Hence, it should be noted, that the original name, given to the 1812, is misleading, as it is not the original name, given to the present 1812, but the name of a species which, I think, is the 1812. It is remarkable, that the 1812 has nothing

TABLE IV

Table IV. Nitrate and nitrogen content of tissues of four plants fed to larvae and adults of *Sphingidae* heterogaea. Sample sizes are 8 and 14 for nitrate and nitrogen content, respectively.

Plant Species	Nitrate Content (% of fresh wt.)	Nitrogen Content (% of dry wt.)
<i>B. coccinea</i>	11.08 ± 2.67 ^a	1.10 ± 0.15 ^a
<i>B. flava</i>	11.10 ± 2.34 ^a	1.08 ± 0.20 ^a
<i>B. gigantea</i>	10.40 ± 2.76 ^a	1.00 ± 0.22 ^a
<i>B. Turneri</i>	10.31 ± 4.36 ^a	1.21 ± 0.23 ^a

^aMean within a column followed by the same letter are not significantly different at the 5% level by Scheffé's Multiple Range Test.

Consequently, the *in vitro* performance of the *in vivo* performance of the drug is not necessarily predictable.

Independent Variable	Year	Indigenous Yoruba			
		1980	1985	1990	1995
High education, 1.00	1980	-0.011	-0.011	-0.011	-0.011
High education, 1.00	1985	-0.011	-0.011	-0.011	-0.011
Female in household, 1.00	1980	-0.011	-0.011	-0.011	-0.011
Family structure, 1.00	1980	-0.011	-0.011	-0.011	-0.011
Female, 1.00% married	1980	0.011	0.011	0.011	0.011
Female, wife absent	1980	0.011	0.011	0.011	0.011
Female, wife absent	1985	0.011	0.011	0.011	0.011
Female, wife absent	1990	0.011	0.011	0.011	0.011
Female, wife absent	1995	0.011	0.011	0.011	0.011
Family size, 1.00	1980	0.011	0.011	0.011	0.011
Family size, 1.00	1985	0.011	0.011	0.011	0.011
Family size, 1.00	1990	0.011	0.011	0.011	0.011
Family size, 1.00	1995	0.011	0.011	0.011	0.011

¹⁰ See, for example, the discussion of the 1992 Constitutional Convention in Part IV.

Opportunities and Feeding Preferences

Given a choice among the four host plants for oviposition, the females tended to prefer *B. Pustulosa* and *B. gracilis*. This preference, however, was not significantly significant. There was a slight tendency to oviposit on their original host plant by females reared on *B. Pustulosa* and *B. gracilis*. Females reared on *B. gigantea* and *B. Intermedia*, however, apparently discriminated against their original hosts, as they chose other BBS plants for oviposition. A similar trend for feeding preference was observed although the differences among treatments were not smaller than those for oviposition and the adults reared on *B. gigantea* and *B. Intermedia* did not clearly avoid their original hosts (Table 3).

The chrysomelid beetle, *Glyptosoma integrum* (LeConte) originally in the genus *Galanga*, was moved in 1980 to the genus *Glyptosoma* by Bern. In 1984, Wilson described the new genus, *Glyptosoma*, composed of three species, two of which are specific feeders on *Salicaceae* spp. (Oates, 1984; Wilson, 1985). *B. integrum* is reported from blue spruce, *Chionia piceiphila*, of the family Lythraceae, by Wilson (1985). Two recent apparently reclassified from Deltsheva and Haga (1977) are reported that the adults of this beetle were collected by a tree grower on a plant he called 'Yamadori' (*Populus peltigera*?). This does not seem to be a very reliable report. *Salicaceae*, and not *Chionia*, appears to be the true host plant of *B. integrum*, since most of the other *Glyptosoma* species are restricted to one host genus, although all three feed on plants of the Malpighiaceae.

This beetle is reported from Pennsylvania, (1977a), Texas (Wilson, 1985) and Vietnam (Deltsheva and Haga, 1977). In California, it occurs

THE JOURNAL OF CLIMATE

Subject Book	Institution									
	Inst. No.	Inst. Chgs.								
Institutional										
1. Economics	21	20	22	17	7	6	18	9	8	1
2. English	41	17	42	11	11	6	11	1	1	1
3. English	31	1	32	1	33	6	34	4	3	1
4. English	33	3	32	3	31	3	30	3	3	1
Institutional										
1. Economics	21	20	22	17	7	6	18	9	8	1
2. English	41	17	42	11	11	6	11	1	1	1
3. English	31	1	32	1	33	6	34	4	3	1
4. English	33	3	32	3	31	3	30	3	3	1

Table 1. Mean objective performance measures for each of the three conditions.

on the four main species of Salicornia: S. pyrifolia var. salina (= S. alpina), S. thalictroides, S. glauca and S. europaea. Both larvae and adults feed on leaves. Larvae appear in the field in early May. They lay a clutch of conical, orange eggs on the underside of the leaf. The clutch size in the field is about eleven to 14 eggs with usually not more than one clutch per plant. Young larvae are green and feed on the sea beet. There are three larval instars. The first instar larvae feed by macerating the leaf. Third instar larvae will make holes in the leaf blade. Prior to pupation the third instar larvae spin a loose web-like sac-like structure of a white milky secretion. In the laboratory, the pupae hatches four days or fifth on the leaf and then pupa inside the covering egg shell to pupae. No pupa was found to pupate in the field. These observations suggest that S. oligolepis, like other species of this genus (West, 1926), pupates in the soil.

Eggs of this species were seen on plants in the field in late in the early October in Bremen-Höft. Adults and larvae may be collected until early November. Development time in the laboratory, the hatching to adult, averages 21 days. Since golden beetles are slow to increase until older, the occurrence of larvae in the field until early November suggests that this species overwinters not only as adults but also Sphingid beetles (West, 1926) but also as pupa, on the soil. Adults were seen on S. thalictroides early in May and one week later they were seen in S. pyrifolia. The adults could be collected in S. glauca and S. europaea late in May and the beginning of June, respectively. They were very scarce in the latter. In the laboratory survival rate of pupae to adults on these latter two species was very low with the individuals

reaching adulthood. These fed *S. gigantea* that add more live to the adult stage than a very short life span (3-10 days).

Several studies have shown the influence of leaf water content on insects on insect performance (Petersen and Southwood, 1959; Rutherford, 1960; Rutherford and Stanley, 1961; Rutherford, 1966). Peltier (1977) showed that fecundity, longevity and weight of the mature female *Phaon eudimela* Rutherford and Rutherford when the diet was fed a leaf with higher levels of leaf nitrogen. Leaf water content is another factor determining plant quality (Rutherford, 1977; Rutherford and Feeny, 1979; Rutherford and Stanley, 1981). Better performance is achieved by goliathid leafhopper larvae feeding on plants which have high leaf water (27% to 48%), as opposed to insects feeding on leaves with leaf water less than 20% (Rutherford and Stanley, 1981). Leaf water content may also have an effect on nitrogen utilization by insects. Larvae of the artemidid moth *Hydriomena fasciata* fed with leaves of low leaf water content grow more slowly and utilized plant nitrogen, energy, and nitrogen less effectively, although their total nitrogen and carbon content of these leaves did not differ (Rutherford, 1977). When water is not a limiting factor (as insects such as *Phaon eudimela* (Rutherford and Feeny, 1979) optimize nitrogen assimilation by altering consumption rate in response to changes in leaf nitrogen content), but when water is apparently limiting nitrogen utilization efficiency and nitrogen assimilation rate, high feeding rates could also result in better growth (Rutherford, 1977). This seems to be the case for *S. gigantea* where performance on *S. gigantea*, which contains low leaf nitrogen but high leaf water did not differ from the performance on *S. glauca*. In some instances the performance on *S. gigantea* was better than that on *S. leucanthemifolia*. Both *S. glauca* and *S. leucanthemifolia* had

higher leaf nitrogen and lower leaf water contents than *S. juncinella* (leaf water content on *S. juncinella*) was even lower than on *S. nigra*). Indeed, leaf water content of the larvae of *S. glauca* and *S. latifolium* was lower than that of any other species (Görner and Rump, 1974). Larvae of adults of *S. juncinella* are external feeders and they may be more susceptible to changes in humidity. Deethsou (1977) discussed the leaf water content as a major evolutionary "variable" for phytophagous insects, and in the presence of the many physiological, behavioral and ecological adaptations to avoid water loss.

The toxic effects of allelochemicals cannot be excluded as part of the explanation of the marked variation in the relationship between leaf nitrogen and water contents and *S. juncinella* performance. Several allelochemicals such as tannins, glycinines and flavonoids have been isolated from grasses of other species (Büller et al., 1976, 1980; Deudekova et al., 1978; Römer et al., 1982). These allelochemicals may interact with an insect's metabolism in such a way that its performance will be less than that expected by leaf water and nitrogen. This was the case in the southern grasses (*Polygonum aviculoides*, *Krause*) where growth response to leaf water and nitrogen was altered by various allelochemicals present in the 11 grass species on which the larvae were fed (Görner, 1984).

Relief of *S. juncinella* were not as successful on fescues, which manage to compensate for the nutrient deficiencies and obtain an average weight close to that of *S. juncinella* raised on *S. officinalis*, the most nutritious host. Compared to males, females either consumed food at a faster rate and/or utilized their food more efficiently because they gained more weight in a shorter time. Females accumulate each of the nutrients and energy provided to eggs during their larval development. For this reason

they are heavier than males and usually have longer developmental times. The aecidial significance of the unusually later emergence of males of *S. lituratus* may relate to the fact that females are not ready for egg laying until two to four days after emergence. If males and female emergence was synchronous, the males would be exposed to several months and to environmental hazards while waiting for the female to emerge. This could increase male mortality and the females might have trouble finding a mate. Those males that emerge later than the females, however, could be more successful in mating and reproducing. Late male emergence may have evolved to the population to this reason.

Survival rates and fecundity were higher on *Salicornia europaea*. This can be inferred that survival rate of *S. lituratus* that feed on this particular host species has greater fitness. It would therefore be expected that, given a choice among the four glasshouse plants, males and females would preferentially feed on *S. europaea* and females would select this host species for oviposition. This was not the case, perhaps because the plants are only closely related to each other and the females cannot discern among them before actually "laying" them. Once they are on a plant they may stay there. In general, females laid their eggs on the plant species on which they were feeding. Host choice by *S. lituratus* would be better understood with a knowledge of their dispersal behavior. When disturbed in the field or in the laboratory, *S. lituratus* does not fly but rather roll in the soil and play dead. Studies on the dispersal behavior of the other beetles of the *Salicornia* delimitation, *Lepturidea marginata*, Leconte and *Lepturidea brevicollis* Kuhn (Pearson, 2002) demonstrated that these beetles exhibit the *pre-embryonic* syndrome, flying only during a non-teneral but pre-adult/sexual stage. They perform long-range

dispersal and colonization of other fields only at this time. This may very well be the case with *S. bilineata*. The greatest fields or habitats are generally composed of only one species. Since the fields, as in the pre-dispersal census of 1967, might contain more fields, *S. bilineata* may become restricted to visiting insects from plant to plant. Because the feeding and oviposition experiments were performed using ovipositing females, their stimulus for nest selection may have already been blocked. They probably were not able to exhibit a "female response" and were simply ovipositing on whatever plant they were in at the time. Field studies of dispersal behavior are necessary for a better understanding of the mechanics of food choice and nest selection of *S. bilineata*.

Host Specificity of *S. bilineata* to *Scutellaria galericulata* (Lindley)

S. bilineata was the only species of *Scutellaria* collected in habitats in Greenwich, although 4 other species of this genus had no dispersal. Two of these other species are polystachys, but *S. galericulata* (Benth and Rivers, unpublished data) and *S. alpina* have been reported only from *Scutellaria*.

Larvae of *S. bilineata* were collected in Greenwich from early May to the beginning of September. An egg was collected in the field on 1st over the axis with on the underside of the leaf. In the laboratory, female field eggs had surface wrinkles on either side of the leaf or on cap cells. Each egg was measured 2.0 to 3.0 mm wide, transparent, lighter in color than eggs. They probably turn yellowish and then reddish brown as the embryo develops. Under laboratory conditions, the eggs took 8 to 12 days to hatch.

Despite eggs being laid in water, more than one larva per plant was rarely seen in the field. The author rarely handled larvae probably dispersed by splashing with droplets in which they swam themselves and moved from the egg and onto the other plants. Late instar larvae were never observed suspended in with threads.

Four gallerific species were reared from larvae of *S. glabratula*, including the leucospids (*Chrysis*, sp., *Leptochilus* sp., *Hymenoepimecis*, sp., *Pimplagaster*, sp., 1 and *Hymenoepimecis*, sp., 2, 1 cleptoparasitic (*Ormyrus* sp., (Linnaeus, 1758) and 1 cleptoparasitic (*Ormyrus*, *feruginea*, (Davis)). The most common species was *Pimplagaster*, sp., 1.

Development and fecundity of *S. glabratula* reared on the four common species of galiums in California are presented in Table 8. The average male developmental time from hatching to pupa ranged from 21.0 to 24.4 days, depending on the host plant they were fed on. It was a little shorter than average female developmental time which ranged from 25.4 to 28.4. The variations within a given sex is apparently related to the nutritional quality of the food. Analyses of leaf water and nitrogen content of the four galiums species used in this study are presented in Table 6. Developmental time of male and female was significantly shorter in *S. glabratula*, the plant with the highest leaf water and nitrogen content. Larvae reared on *S. gracilis* were greater, the host with significantly lower leaf nitrogen than the longest time to develop, but the difference in developmental time on this species and on *S. glabratula* and *S. intermedium* was not statistically significant. These results are in agreement with those observed for the beetle *Epuraea leprosa*, (Fabricius) in the previous chapter. The low leaf water content of the latter plant species may have had low nitrogen assimilation efficiency

Table 8. Impact and width components of household savings on the standard of living, 1980-1984.

Year	Type	Impact		Width		Impact		Width	
		Impact	Width	Impact	Width	Impact	Width	Impact	Width
1. <i>constant</i>	0.01 + 0.04 ^a	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04
2. <i>discrete</i>	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04
3. <i>discrete</i>	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04
4. <i>discrete</i>	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04	0.01 + 0.04

Percent change in current per capita household income from a 10 percent change in the standard of living.

Numbers in parentheses indicate standard errors.

and nitrogen accumulation rate by the larvae. The main effect of the humidity and other factors such as ultraviolet-b on the nitrogen utilization by insects is discussed by Donher (1977). The developmental time of males and females of *S. glaucoptera* was inversely correlated with leaf nitrogen content (Fig. 6, a and b). The number of adults reared on each host plant (Fig. 6, c) and the number of eggs laid/female/day (Fig. 6, d) were directly correlated to the amount of this nutrient on the food plant. Leaf water content did not show any direct effect on development, survivability and fecundity as shown by the low correlation coefficients between this variable and the measure of larval and adult performances ($r = 0.22$ and $r = 0.40$ for male and female developmental time, respectively, $r = 0.11$ for number of adults reared, $r = 0.21$ for number of eggs/female/day). None of the coefficients was significant. The only effect on survivability and fecundity was also not apparent, since the number of adults reared and the number of eggs laid/female/day was consistently higher on the hosts with higher leaf nitrogen content, even if the leaf water content was low. *S. glaucoptera* has a behavioral adaptation to prevent water loss by taking the leaves to each other forming a protective case. Small variations in the moisture content of the diet may also strongly affect the performance.

Although causing an increase in the developmental period of *S. glaucoptera*, low leaf water and nitrogen did not affect the weight of the pupae. Larvae of *Platynota* species adjust their feeding rate to compensate the low nitrogen content of the diet. By decreasing their rate of food consumption, they maximize the nitrogen accumulation rate, thus increasing their growth rate (Hansky and Feeny, 1977). The nutritional need of a larva is to receive an adult with high fitness. The weight of

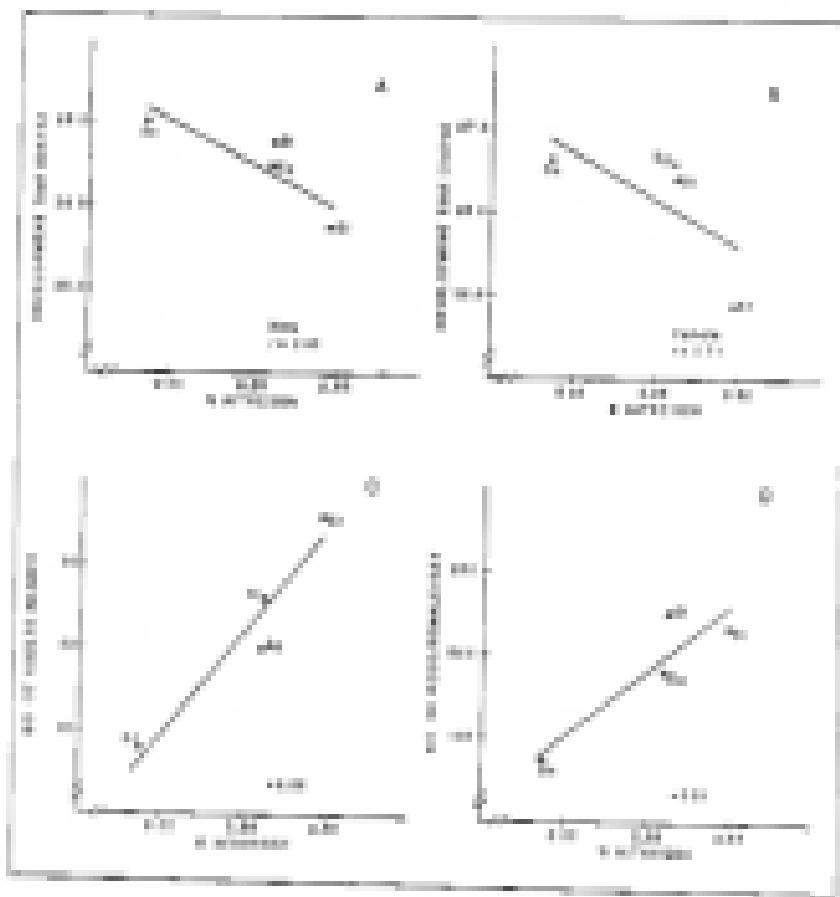


Figure 8. Developmental time of males (A) and females (B) of *Sparmassina oblonga*, number of adults hatched (X) and number of eggs/oviposition day (Y) in relation to total nitrogen content of the larvae of four species of *Sparmassina*. \square = *S. oblonga*, \circ = *S. oblonga*, \times = *S. oblonga*, \bullet = *S. oblonga*.

important as a rearing factor in this species and when faced with the nutritional quality of its diet, the larva may have to eat for a longer period of time to attain a similar body weight (Krasupi, 1982). *S. affinis* pre-dates on *S. paradoxus*, *S. giganteus* and *S. leucospilus*, but attained approximately the same body weight in relation to *S. fuscipes*. This did not result in equal fecundity as would be expected. When CHED reports that heavier or larger adults of insects belonging to several orders, including Lepidoptera, tend to lay more eggs than small ones, adults of *S. affinis* only fed on *S. paradoxus*, so the energy and nutrients provided to eggs was probably stored during larval development. Although the larvae attained a similar body weight in relation to *S. paradoxus*, they did not accumulate enough nutrients to provide for adult egg production when fed on *S. paradoxus*, a nitrogen-deficient host.

Field studies are needed to determine the number of generations a year, the determinating stage and the mechanism of dispersal and host selection of *S. affinis*.

Plant Architecture and Larval Biology

The architectural complexity of *Salticus paradoxus*, *S. fuscipes*, *S. giganteus* and *S. leucospilus* were determined by measuring plants at four different growing stages in 1988. Each time the plants were measured, the insect population was surveyed. In 1988 the surveys were repeated on *S. paradoxus* and *S. leucospilus*, two time in their growing stages. The TMR data were first analyzed separately to detect variations in plant structure among species, insect and month. The three parameters used as determinants of the plant architecture, height of plant, total leaf area (number of leaves x average leaf area) and size of flower stalks (number x average size of flower stalks) were

significantly different among the seven locations and the four months. The interaction between month and location was also significant (Table 11). These results indicate that location, and not plant species, was the main driver of variation. Table 12 shows the interaction terms between location and month for height, total leaf area, size of flower stalks, number of phytophagous insect species, number of beneficial species (including insects, spiders and *Opiliones*), and total number of species.

Results of the statistical analysis of the 1993 and 1994 data assumed yielded results similar to those obtained for 1993 only (Table 11 and A3), with significant interactions between years. Thus only 1993 results were used to further compare locations in their species/architectures relationship, since only four locations were targeted in 1994.

Because of the significant interactions observed among location and month, it was sensible to use these two variables as replicates in the correlation coefficients and regression analysis. These tests were applied to determine which characteristics of foliage plants accounted for the richness of the insect fauna associated with them. The following were the parameters included in the total height of the plant, total leaf area, "Perrill architecture", "vertical architecture", leaf nitrogen and leaf water content. The "Perrill architecture" was calculated by combining height + total leaf area + size of flower stalks. The results were ranked according the criteria in Table A3. Once, unlike the other resources, nectar is produced by the plants basically to attract insects, and only a few species exploit the flowers and seeds of the pollinators as

They are not to be found in any of the books of the period, and the author of the present paper has not been able to find any reference to them in any of the books on the history of the English language.

In absence of PDS, a 'partial architecture' which included only height and total leaf area was also calculated.

The above attributes of the host plant were better related to the number of phytophagous insect species, the number of beneficial species (parasites and predators, including aphids and fly larvae) and the total number of species (phytophagous and beneficial) (Table 2b). The results indicated that total leaf area better explained the diversity of the insect fauna of ginkgoes. Height, size of fruits and 'partial architecture' were not linearly related to species richness, enough for a negative correlation existing between height of plant and number of beneficial insects. Thus, increasing the architectural complexity of the plant by size and/or of flower stalks did not result in an increase in the number of phytophagous insects. Partial architecture was linearly related to the number of phytophagous species ($r = 0.40$, $P = 0.01$), but not to the total number of species. The diversity of ginkgoes' phytophagous fauna shows a positive correlation with total leaf area ($r = 0.39$, $P < 0.001$). The complexity of the foliage also explained part of the variation in the total number of species associated with these plants ($r = 0.38$, $P = 0.001$ (Fig. 2)).

Each insecticidal and their each species were next tested for their relationship. Again total leaf area better explained phytophagous and total species richness, but the correlation coefficients were not significant because of the small number of observations (Fig. 3).

The seasonal building of the phytophagous fauna and of evolution of the total species of ginkgoes in December are shown in Fig. 4.

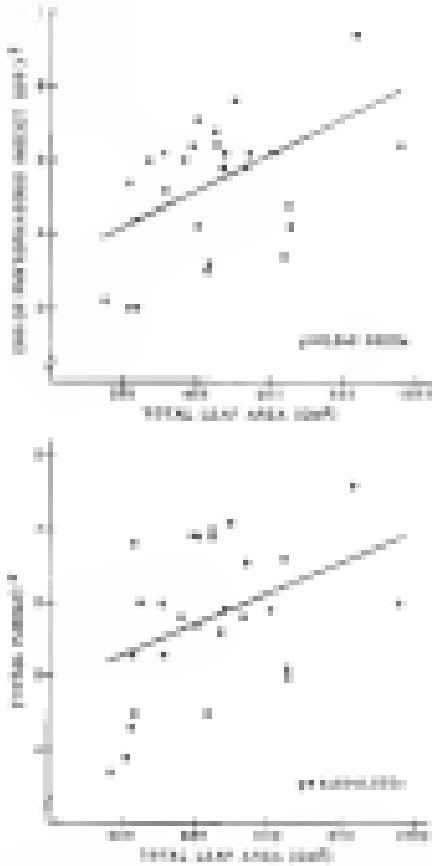


Figure 7. Square root of the number of phytophagous insect species and square root of the total number of species in relation to total leaf area of the host plant ($r = 0.53$ and $r = 0.56$, respectively).

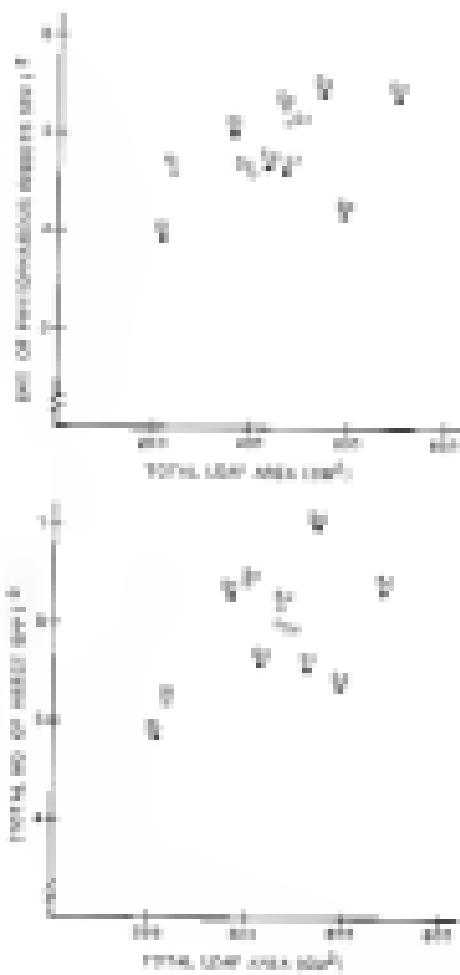


Figure 5. Relationship between total leaf area and the square root of the number of physiognomies (number of species) in 1990 (-) and 1995 (-).

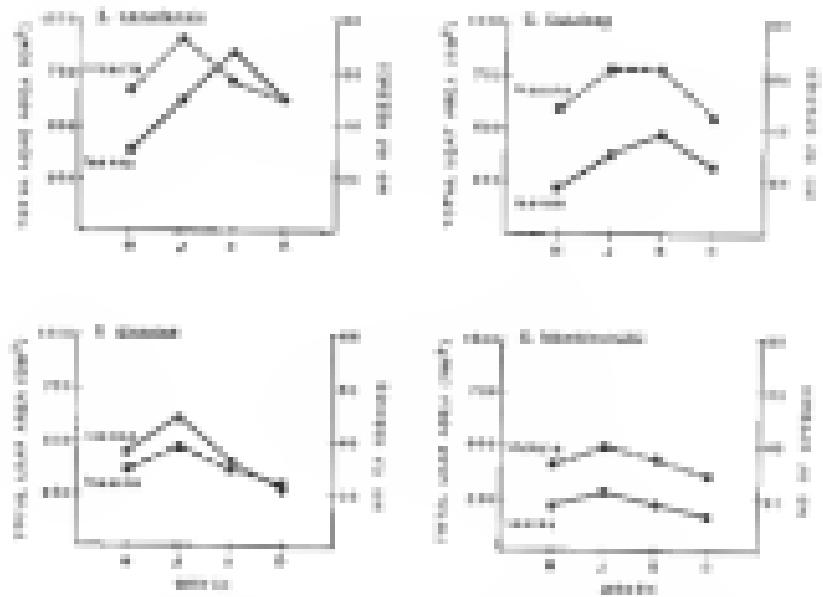


Figure 6. Seasonal changes in total leaf area (as a measure of the plant growth texture) and in the number of phytophagous insect species on their galled species.

Except for *B. gigantea*, the correlation coefficients between total leaf area (used as a measure of the plant architecture) and the number of phytophagous insects were neither low nor significantly linear, perhaps because of the small sample size (mean values of total leaf area and only one adult per unit of number of insects). When the four species were analysed together, the correlation was significant ($r = 0.51$, $P < 0.05$).

The richness of the insect fauna associated with a given plant is a function of several factors, the principal one being the plant's geographical origin. Plants grow widely distributed appear higher insect diversity (Strong and South, 1980). Within the same geographical origin, large, structurally more complex plants are more species-rich than small, structurally simple ones. Plants with the same growth form may still show differences in the insect fauna as a result of local variation in the plant population characteristics, such as height of the plant leaf area and number of related species (Jouffre and Prieur, 1978).

Nevertheless, 10% of the total number of phytophagous insect species associated with *gigantea* in Guatemala were leaf feeders. Thus it is not surprising that the availability of this resource accounted for most of the observed variation in insect species number among the collecting sites. Meesha and Root (1980) showed that the leaf miners, *Spirorbis*, *Agromyzidae* (detected) and *Elachistidae* (detected) differentiated against *Calliopsis grandis* (L.), a distinctive gallworm with unique foliage which may be selectively utilized for the large infestations of *B. gigantea*. Among the four species of gallworms in Guatemala there is a great variation in leaf form, from the narrow, arrow-like leaves of *B. leucogrammus* to the larger, wider leaves of *B.*

species). The number of phytophagous species associated with each plant from 1988 to 1993 generally followed this gradient, with very few insects collected on *L. leucocephala* compared to the other plant species. The number of insects also followed the seasonal building of the foliage. Late in the season, when the leaves started to fall, the number of insects dropped, although the overall architectural complexity of the plant increased due to the addition of flower stalks. Thus, increasing the architectural complexity of the plant with flower structures did not result in an increase in the number of insect species. Only two insects that feed on these end leaves, a small moth and a weevil, are specific to *L. leucocephala*. Other insects exploiting these structures are polyphagous or feed elsewhere on other parts of the plants. Different species are utilized by different insects and none of them seem to be specific to the plant. Since these plants also reproduce vegetatively by rhizomes, resource allocation to sexual reproduction may vary with age, from year to year and perhaps with environmental conditions. In this sense, different species could be considered as reproductive resources and they are expected to be utilized by only a few specialized insects.

Height alone had no effect on species richness but when height and total leaf area were combined there was a small but significant correlation with the phytophagous fauna. However, height and total leaf area are correlated with each other, and the above relationship may result from the fact that, up to a certain point, in the grazing system, taller plants have more leaves.

No other studies have attempted to explore the role of the plant diversity on the diversity of the white-tailed species, including predators and parasites. Here it is shown that foliage complexity has a

per² had detectable effect on the total arthropod fauna of *giantreed*. This significance, however, may be only a residual effect of the highly significant linear relationship existing between the total leaf area and the phytophagous fauna. Mean natural enemies only are correlated with leaf area in the relationship is negative and not significant. This fauna also shows a significant but negative relationship to height. It seems, however, that the observed negative relationships are only a matter of coincidence. Natural enemies may be abundant on a given plant for reasons that are not related to the plant morphology. Plant density and plant population size affects the herbivore population (Orts et al., 1980). Increased plant density implies higher resource availability to herbivores, resulting in larger populations which will attract more natural enemies to the plant. Associated plants which are a source of nectar and pollen to visitors, predators, and parasites may attract larger numbers of natural enemies to the host plant (van der Valk, 1980). The presence of insects producing barklures is also attractive to natural enemies (Orts et al., 1980). The largest entomophagy rates observed in the present study occurred at B. B. (but not B. B. 100), to which *giantreed* plants were infected with *ashleyae* during most of the growing season. Several species of aphids were constantly collected, as well as other predators and parasites. The highest hystrix rate was observed at B. B. 100, which was the largest patch and where plant density was up to four times higher than at the other locations. The third highest hystrix rate was found at a location with high plant diversity (Orts study) where the *giantreed* plants grew mixed with a variety of other flowering weeds. Their observations confirm the results of former studies related to abundance of natural enemies. They suggest that the

surrounding vegetation, the structure of the insect community and host plant density determine the diversity of predators and parasites. The results also suggest the role of many biological control actions. The fleshy corolla of natural vegetation growing between the arable crop fields to increase diversity and offer alternative food and shelter for natural enemies (Hiltner, 1990).

The within-species variation in plant structure and insect diversity indicated Price and McNaught's (1989) observation of the importance of environmental conditions in determining population size of herbivores. These authors surveyed six species of artemisia which occurred in order on a moisture gradient from wet to dry soil conditions. Plants of the same species growing in very moist conditions were richer in herbivore visitors and abundance. The study was restricted to 10 insect species to be efficient. It was necessary that the band conditions directly affected survival and development of some of these species, such a gradient of visitors was not observed among florations occupied by the same gathered species or among all localities. Effect of environmental conditions on performance of a particular insect was also not observed, since the whole fauna not being studied. But evident was the environmental effect in the plant, which in turn affected insect diversity. Populations of the same species under different physical and environmental pressures grow differently and in consequence supported different insect fauna. For example, *S. gummiferus* growing on B. P. West was taller and had more total leaf area than at the other localities.

Certain insects may also affect the growth rate of the plant. In 1994, the population of *S. gummiferus* growing on Bally Potej was heavily attacked by *Tephritis conura* (Diptera: Tephritidae). Larvae of this insect

here into the growing tip, interrupting the terminal growth of the plant and inducing lateral growth of two or more branches. Such growth produced flower spikes and thus significantly increased the overall architectural complexity of the plant.

Another factor influencing insect diversity at *gilia* was the density of the host plant abundance. *S. diffusus* growing at 20–30 days supported more phytophagous and beneficial arthropods than at 40–45. Overall richness was greater at the former location than predicted by the spatial leaf area, as shown by the deviation from the negative line in Fig. 8. Plant abundance was responsible for some of the variation in the number of different arthropod species associated with *Gilia* cases (Boučeková et al., 1992). High densities influence the nutritional quality of the foliage, concentration of nectar and tannins, microclimate (Price et al., 1993) and infestation rates (Strong and Lewis, 1979). Abundance of *S. diffusus* at 20–30 days was 2.4 to 4.1 times greater than at the other locations. *S. diffusus* populations are also the largest among all, with more resources available to the insects. These facts probably had a significant influence on the number of insect species at this location.

Relocation of the insect collections using the four *gilia* species to similar locations. Differences between *S. integrifolius* and the other host species might be related to the architectural complexity. The narrow leaves of this plant form a sparse canopy which probably allows more exposure to wind, insulation and other climatic. Contrarily, *S. californicus* and *S. diffusus* form a more dense vegetation where the insects are shielded and sheltered. *S. diffusus* was more species than the other *gilia* species in Sonoma. Insects are more likely to find and colonize hosts more frequently distributed. Perhaps one

Manoli (1981) showed that plant frequency explained some of the variation in the number of leaves of *Hordeum vulgare* on Finnish heathland from wet sites. *G. paniculata* is commonly found on heathland, *Poa* from wet and old fields to *Salicetum*, and this may be partially responsible for the larger number of insect species associated with this host.

The fact that *G. glauca* supports a smaller number of insect species than *G. paniculata*, although the latter has smaller total leaf area, is probably due to the density effect discussed earlier. However, as opposed to the other *Hordeum* species and plant cover in Fig. 8, the insect survey of *G. glauca* is under that of the plants, perhaps indicating that H's foliage is under-exploited. *Scirpus* has the only population of *G. glauca* found and it appeared mainly *Scirpus*-like there. It may be that the plant grows associated with many other hosts. Host plants growing associated with other plant species may be less attractive to insects because the latter are marked by volatile chemicals produced by the other plants (Price et al., 1982). Thus, it seems that *G. glauca*, growing on *Scirpus* Hs, is less apparent than the other *Setaria* species because of the scarce of坐tuation and competition with many other plants, and this affected the diversity of the insect fauna. The possibility that most insects visit *G. glauca* or *G. incanum* due to the low water content of their leaves or to the presence of allelochemicals cannot be discounted. It was shown by the previous studies of this chapter that these two species had low water content which may low foliar nitrogen assimilation efficiency by the health *Scirpus* (Meyer and the 1981 *Scirpus* study). Water is an important factor limiting productivity (Bartholemé, 1972) and could very well

in determining the nature of insect species associated with *S. glauca* and *S. laciniata*.

The protective chemical or physical defenses of plants may also play an important role in insect species diversity. Part of the toxins on a plant may not be available to the insects due to the accumulation of allelochemicals (Perry, 1984). Polyphagous phytophagous insects may be adapted to overcome such nutritional problems (Lewis, 1991). They could significantly enrich the fauna of plants with the chemical defenses. They would, however, avoid those plants displaying a battery of defenses including qualitative and/or quantitative chemicals and low levels of nutrients. Only the insects adapted to overcome these nutritional problems would inhabit these plants. In this case, a more vigorous foliage may not result in a richer insect fauna associated with the plant, since the insects would be able to exploit it. Research on the chemical composition of the four galbanum species is necessary before the influence of protective chemicals and nutritional quality on the nature of insect species associated with them can be understood.

In Bahoruco, galbanum seedlings appear in March. Bush seedlings produce a long, thick stem which originates from a root or rhizome node. These are added to the stem as the plant grows until late summer, when the resources begin to be allocated to reproductive structures. Several aerial stems arise from one place, but in this study, each stem is considered an individual plant. No branches are produced. The growth of the vegetative parts of the plant is represented by elongation of the stem and addition of leaves, which are larger and/or more numerous. The structures are added to the flowering season, when the plant starts to produce flower stalks. The availability of these are

structures, however, my net result is some architectural complexity of the plant, since it is my collection with increasing and dropping of many leaves. The overall complexity of a plant species of Salvia slightly increases (S. divaricata and S. greggii) or decreases (S. dumetorum and S. leucophylla) in the fall.

In separate regions, there is a seasonal progression of the insect fauna on a plant. The number of phytophagous insect species on a plant of Salvia increases gradually, reaching a peak in late July and early August (Linton, 1970). In a floristic analysis of these data, the author suggested that the variation in number of species of phytophagous insects was due to a fluctuating quality of leaves as food during the growing season, because most of the time the quality of protein in the plant is considerably below that usually regarded as optimal for many insects. At the same time, the levels of toxins, tannins, and alkaloids increase. Linton's findings were very similar to those of Lampy (1930) in Texas, and both authors agreed on the plant chemistry explanation for the regional variation in the phytophagous fauna of insects and etc. In further discussion of these findings, however, Linton (1970) suggested the idea that plant architecture instead of plant chemistry might better explain the variation in the number of insects throughout the year. In the leaf blade aspect, the broader broad leaves are architecturally more complex, so that in a mature plant it is possible for different species to exploit very different microhabitats and microclimat conditions such as the basal plane or the plant tip. This idea is substantiated by the studies of Peter (1969) on *Agave* which show a parallel increase in habitat space (as a measure of plant development) and in insect diversity. Gossypio (1970) found that the seasonal succession in quality

of herbivores and represents reflected seasonal changes in the plant structure in the soil herb communities.

The seasonal behavior of the photosynthetic rates of the four species of *gilia* found in Bateman's plots to reflect both the architectural and chemical composition of the plant. For all four species, the curves describing the seasonal progression of the leaves from closely fit the integrated cell model proposed by Larcher (1980). For the interaction between plant architecture and chemical defenses during the growing season of a perennial herb, Bateman's repeat curves show a sharper drop in photosynthetic quality with the age of the plant. This effect is especially seen in *G. paradoxa*, the plant species with a more complex foliage. An analysis of the changes in the chemical composition of the leaves of the four plant species throughout the year would directly show the effect of the chemical and architectural complements on the seasonal succession of herbivores. Brief analysis of the curves in Fig. 8 suggest that, in the smaller species (*G. tricolor* and *G. heterosepala*), plant architecture accounted for most of the variability in the total production, while in the bigger and more complex plants (*G. paradoxa* and *G. speciosa*) chemical composition played no important role. Perhaps large plants displaying an abundance of fruit and shelter utilize more chemical defenses against insect attack. Analysis of nitrogen and water content taken from leaves in the sheath of the growing season (July) showed that *G. speciosa* has a lower nitrogen content. There is evidence that nitrogen content of leaves decreases with age (Hanson, 1980; Johnson et al., 1984). The nutritional quality of *G. paradoxa* might become very poor late in the growing season and although there is

an abundance of Urtica, it is not really available to the visitors. Some of J. glauca are not the individuals which respond to J. dubia and J. leucophylla. It's leaf water content is too low to be comparable to that of J. leucophylla. These observations suggest the idea advanced before that J. glauca may have protective chemicals which help insect utilization.

In summary, the complexity of the foliage seems to be the main factor determining insect species richness associated with Urtica spp. to Urticaria. However, environmental factors and plant density influence variability within the same species and among species. Chemical composition and nutrient status may be the possible explanations for the reversal patterns observed when the above factors are excluded. The seasonal build-up of the phytophagous fauna seems to follow the chemical and architectural changes in the plant during the year.

Although native Turks tend to have a more specialized fauna, the great majority of phytophagous insect species utilized in gaitheria are generalists. This is related to the fact that only one species of thrips, the most represented group, is specific to gaitheria.

Among the insects which feed only on gaitheria and aztec, three species are considered to be potential biological control agents: one attacking roots, *Tanysa pana* (cane) (Tephritidae), the leaf miners, *Spacelia longa* (Drosophilidae) and *Spacelia glabra* (Drosophilidae), one leaf miner, *Amphicnemis* sp. 1 and *Conotrachelus* sp. 1 (Curculionidae), one attacking flowers and seeds, *Lepturges maculatus* (Elachistidae) and *Jamesia annua* (Elachistidae).

Only three insect pests of economic crops were found to gaitheria. All were leafhoppers: the northern plant louse, *Uroleucon linearis*, the southern green orchid louse, *Uroleucon vicinum* and the white *Uroleucon pallidum*. These species, however, are highly polyphagous, and may be found associated with many other weeds. Thus gaitheria growing in an over-agricultural system should not be considered a threat to crop fishes for feeding these pests.

On the other hand, gallinaceous are an invader for many native species. Both adult gallinaceous and parrotlets are attracted to this plant for nectar and nectaries and 41 species of visitors were found associated with gaitheria.

The water and nitrogen content of the leaves of the four *Schizogyne* species studied had a significant effect on the performance of the beetles *B. fagiella* and the moth *B. disticta*. Both insects developed faster and had higher survival rate and fecundity on *S. stellata*, the host with high leaf water and nitrogen content. Although *B. disticta* had a significantly lower leaf nitrogen content, the insects' performance on this host did not differ from that on *S. gigantea* and *S. leucostachys*. Low leaf water content of the last two species may have inhibited nitrogen assimilation efficiency and nitrogen accumulation rate by the larvae of the two insect species. The direct effect of low leaf water content was more evident on the performance of *B. fagiella*, which is an internal feeder, than in *B. disticta*, which is a leaf tier and thus relatively more protected against desiccation. Leaf nitrogen content is the principal factor affecting the development of the moth.

Total leaf area was the main factor characterizing insect species diversity of arthropods. Plants with more foliage harbored an order of twice as many leaf area as those with lower foliage. The overall abundance of the plant was not correlated to species richness because the addition of *Piper* stalks is not followed by a significant increase in the insect fauna. Height of the plant seems to have an indirect effect on insect species diversity because, up to a certain point in the growing season, higher plants have more leaves. Height alone did not significantly affect the number of insect species associated with the plant. Environmental factors affected plant growth which in turn caused variation in species richness among populations of the same host species. Plant abundance also influenced insect diversity

because more resources were available to herbivores. The richness of the beneficial fauna is not related to the plant structural complexity but to other factors such as the presence of insect-predating herbivores, total plant density and the presence of other flowering plants.

Still, unexplained variation in the number of insect species associated with grasslands was attributed to chemical defenses and nutritional quality of the host plant. Further studies are needed to test this hypothesis.

APPENDIX

Analysis of variance and correlation coefficients of the measures of the architectural complexity of the four test plans, and analysis used to derive the architectural rating.

Table 21. Results of variance on height, total leaf area and size of flower stalks of *gracilis* plant at three different locations.

Number of replicates	df	Height	Total leaf area	Size of flower stalks	
Plant Number 1001					
m^2					
Location (L)	4	47905.72***	100245.82***	19251.30***	3
Year (Y)	3	610901.23***	106216.89***	211941.19***	3
L x Y	12	2661.72***	146211.28***	16.831.19***	3
Error	108	251.27	15631.13	10568.47	Ind.
1002 + 1003					
m^2					
Location (L)	3	34456.52***	911307.99***	14386.10***	3
Year (Y)	2	4292.13***	204077.12***	243826.06***	3
L x Y	6	185.11***	117023.59***	38754.73*	3
Year (Y)	2	411324.25***	400003.15***		
Year (Y)	2	2928.79***	191431.16***		
L x Y	6	2781.27***			
L x Y x Y	6	1113.17***	118676.49***		
Error	104	126.26	21123.17	10498.23	Ind.

*, **, *** P value significant at the 5%, 1% and 0.1% levels, respectively.

* σ for size of flower stalks.

Table A6. Criteria used to derive an architectural rating for four types of softwares.

Criteria	Weight	Score				
		1	2	3	4	5
Reliability	Prog.	0.00	40-50	60-70	70-80	80
	Code	0.10	50-60	70-100	110-120	120
	Dept.	0.25	120-150	150-175	175-200	200
	Obt.	0.60	200-250	250-300	300-350	350
User Area	Prog.	0.00	200-300	300-400	400-500	500
	Code	0.00	300-400	400-500	500-600	600
	Dept.	0.00	300-400	400-500	500-600	600
	Obt.	0.00	300-400	400-500	500-600	600
Human Factor	Dept.	0.05	120-140	140-155	155-170	170
	Obt.	0.05	180-190	210-220	230-240	240

Table A3. Correlations of measures of the architectural complexity of tall-herb plants with the number of insect species associated with these.

	Height	Total Leaf Area	Specific Architecture	Partial Architecture
Correlation Coefficients				
Phytophagous	0.34	0.33**	0.13	0.42**
Herbivorous	0.39*	0.33	-0.39	0.20
Total	-0.17	0.33*	0.09	0.33

* $p < 0.05$; **Correlation coefficient significant at the 0.1, 0.05 and 0.01 levels, respectively.

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